NSRP-0227

January 1986

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

The Economics Of Shipyard Painting, Phase One: (Of Three Phases)

U.S. DEPARTMENT OF TRANSPORTATION
Maritime Administration
in cooperation with
Avondale Shipyards, Inc.
New Orleans, Louisiana

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THE ECONOMICS OF SHIPYARD PAINTING,

PHASE ONE:

(OF THREE PHASES)

JANUARY 1986

U.S. DEPARTMENT OF TRANSPORTATION

MARITIME ADMINISTRATION

PREPARED BY

PETERSON BUILDERS, INC.
STURGEON BAY, WI 54235-0047

IN COOPERATION WITH

AVONDALE SHIPYARDS, INC.
NEW ORLEANS, LOUISIANA

FORWARD

This research project is being performed under the National Shipbuilding Research Program, specifically under the purview of Panel Q23-1,. Surface Preparation and Coating, of the Ship Production Committee of SNAME. report covers the first phase (first year) of a three phase (three year) effort that will examine The Economics of Shipyard Painting. The first year has dealt-with the problem of identifying the constituent parts of painting and surface preparation costs within the shipyard.

Mr. Gary Higgins and Mr. Daryl George of Peterson Builders, Inc. serve as Project Manager and Principal Investigator, respectively. In addition, University of Wisconsin - Platteville student interns provided the necessary data collection and computer programming support. Mr. John Peart, Chairman of Panel 023-1 during the Project, served as the Research and Development Program Manager. Avondale Shipyards, Inc. has responsibility for technical direction of the Project and publication of, the final report.

We appreciate the support that Mr. Robert Schaffran and Mr. Joel Richard of MARAD have given toward this Project. We also extend special thanks to the shipyards that allowed us to examine their operations with respect to The Economics of Shipyard Painting. Appendix A provides a listing of the companies and individuals who contributed to the development of this Project.

THE ECONOMICS OF SHIPYARD PAINTING

(PHASE I)

EXECUTIVE SUMMARY

The shipbuilding industry has a complex environment. History has proven that the.amount of labor involved in constructing a ship can be difficult to predict. Some say that the mass production operation found in high volume manufacturing has little in common with the job shop found in shipbuilding, and that traditional Industrial Engineering techniques are therefore unsuitable for treating problems in shipyards. The basic question is whether an end product cost associated with a complex component in a ship can actually be predicted.

Studies at several U.S. shipyards under the National Shipbuilding Research Program suggest that it is, indeed, possible to produce effective estimates of work content, worker performance, and cost in the shipyard environment, and to use this information toward control of actual costs. Pipe Fabrication, Sheet. Metal, and Electrical shops have been the target of these studies, and have shown successful results. There remains one area that has continued to defy estimating, however, and that area is Painting. The painting operation is somewhat unique among shipyard trades in that the end product of the Paint Department is extremely susceptible to damage by other trades. The resulting rework costs are generally quite high. Rework costs are usually folded into the total painting cost, without separate identity. The high total painting cost, therefore, may suggest that the basic painting took more hours than were originally scheduled, whereas the true reason for the high cost was rework caused by other trades. Separate identity and tracking of the cost drivers in the painting area are essential to resolving the problems that are truly responsible for high painting cost.

There is an added incentive for increasing the productivity of the painting operation with respect to rework, and this is associated with the critical role of the paint Department in the zone outfitting concept. In fact, of all the shipyard trades, the Paint Department assumes the most important role as an identifier of zone outfitting problems, Which manifest themselves as painting rework and touchup late in the construction cycle.

With the above as background information, the objectives of this Project can be stated simply, as follows:

Phase I - Identify the individual painting operations, and their associated costs, that together make up the total painting cost.

Phase II - Produce statistically-based estimating factors for painting, using the data from Phase I, and use these factors to predict painting costs.

Phase III - Establish a system for recognizing painting cost variances from the estimated values, so that shop management can control the painting operations.

This phase of the project has closely paralleled the construction of four 255 foot Auxiliary Rescue Salvage (ARS) ships for the U.S. Navy. Due to relatively tight construction schedules, ARS-50 (which was the prototype for this class) was not extensively pre-outfitted. These conditions allowed for the collection of detailed labor cost data for painting on ARS-50 for use in conjunction with corresponding data on the three following hulls. Through analysis of these sets of data, it was determined that painting related cost savings of approximately $240,000 per hull could be directly related to the effective use of zone outfitting techniques. These data were also used in a computerized model designed to determine the cost impact of not installing certain types of items prior to painting.

These data also reveal that when searching for cost savings in the paint area, the collateral activities like cleaning, taping, etc. should not be overlooked. The Phase I data show that only about 10% to 20% of the total painting manhours consist of actually laying paint; the bulk of the manhours are spent on other operations, related to the process of laying paint but separately identifiable and worthy of individual treatment.

. The key to success in this Project is a system for-separate and deliberate collection of labor expenditure data for each of the several segments of the painting operation. Painting costs must be collected and monitored at this detailed level in order to provide a database for future improvements. Labor expenditure collection at the Job Cost level is simply not adequate for this purpose. Such a detailed labor reporting system has been established during Phase I, and is providing reliable data at this detailed level. Phase II will use these data to derive statistically-based estimating factors for the various operations involved in the painting area. Phase III will establish a system, based on these estimating factors, for early recognition of cost variances, a system designed for daily use by shop management. By the end of Phase III, the goal of a total cost control system for the painting area will have been realized.

TABLE OF CONTENTS

THE ECONOMICS OF SHIPYARD PAINTING

(PHASE I

1.0 INTRODUCTION

During the past decade, substantial changes have occurred in the world shipbuilding market that have forced shipyards to pay closer attention to cost saving measures. Remedial efforts have been directed at the traditionally larger departments in the shipyard - piping, electrical, and hul1 - in search for improvements. Unfortunately, the surface preparation and coating departments are often thought of as making purely cosmetic contributions to the ship, and have therefore been left out of the cost saving picture. This type of thinking is changing, however, due to the influx of zone outfitting technology as an accepted and highly economical method of ship construction. The advantages of zone outfitting, accompanied with the. need for more competitive estimating, have created a tremendous need to establish an accurate database of painting costs that can support detailed analyses in these areas.

This report deals with the identification and collection of surface preparation and coating costs with respect to four steel-hull Auxiliary Rescue Salvage (ARS) ships being built by Peterson Builders, Inc. Although the report deals” almost exclusively with ARS class ships, the cost identification techniques employed have been designed so.that they can be applied to nearly any shipbuilding contract.

The initial goal of this Project was to identify the costs of painting, both direct and indirect. Although the original Project called for identifying only the costs of painting, it became readily apparent that the identified costs, properly collected, could be used for several useful purposes, such as bid stage estimating, departmental planning, etc. The Project was therefore expanded to put in place a data collection scheme in the painting area that would support a second year effort to develop bid stage estimating, and a third year effort to establish a system for earlier recognition of cost variances. A portion of this report is therefore devoted to an explanation of the data collection system that has been established for use during Phases II and III of this project. -

2.0 SHIPYARD CONDITIONS DURING PHASE I (1985)

2.1 ACTIVE CONTRACTS AT PBI

Four - Auxiliary Rescue Salvage (ARS) ships - 255' - Steel
Three - Mine Countermeasure (MCM) ships - 224' - Wood
Seven - Yard Patrol (YP) boats - 108’ - Wood/Alum

2.1.1 The ARS Ships will support the state-of-the-art MK 12 Surface Supported Diving System (SSDS) and the MK 1 USN Divers Mask to a depth of 190’. Each ship will also carry a recompression chamber for treatment of diving related accidents. The lead ship, ARS 50, is pictured in Figure 2.1. The characteristics and features of the ARS-50 are listed in Figure 2.2. Phase I of this Project has concentrated on the painting operations associated with these ships.

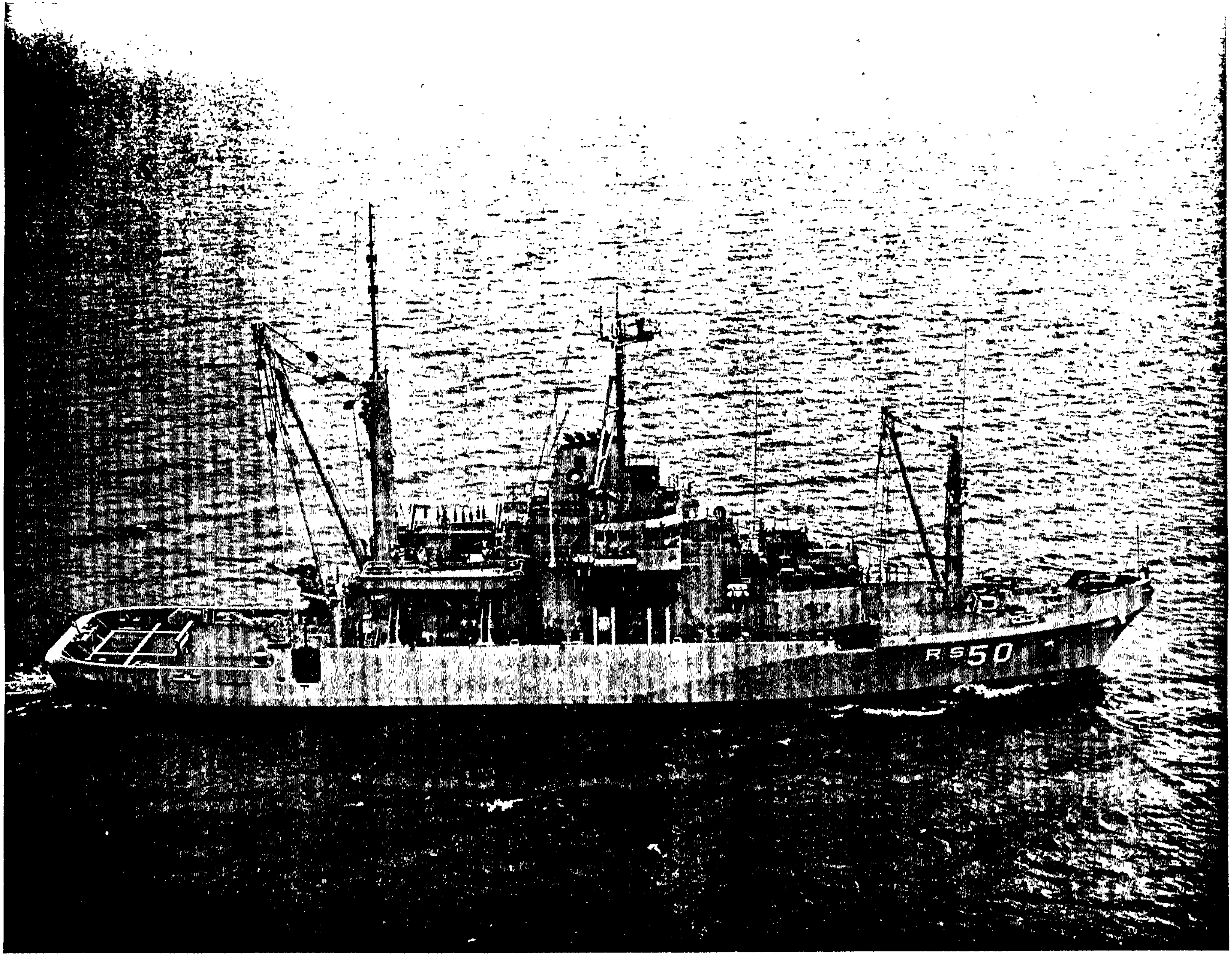


FIGURE 2-1: USS SAFEGUARD (ARS-50)

USS SAFEGUARD (ARS-50)

BUILDER	Peterson Builders, Inc. Sturgeon Bay, WI
CONTRACT DESIGN	Naval Sea Systems Command Washington, DC
DETAIL DESIGN	John J. McMullen Associates Newport News, VA
LENGTH	255'0"
BEAM	51'0"
DRAFT	16'7"
DISPLACEMENT	3193 LT.
SPEED	14.5 KTS
CREW: OFFICERS	7
ENLISTED	92
PROPULSION	(4.) 1200 Horsepower Diesel Engines By Caterpillar Engine Co.
REDUCTION GEARS	GECof England
SHAFTING/CPP PROPELLERS	Bird Johnson Co.
BOW THRUSTER	Brunvoll
SHIP SERVICE GENERATORS	(3) 750 Kw General Electric Generators with Caterpillar Engines
BOILERS	Cyclotherm
SHIP CONTROL SYSTEM	Henschel
MACHINERY CONTROL SYSTEM	Eldec
SWITCHBOARDS	Nelson Electric
CATHODIC PROTECTION	Englehard Industries
ANCHOR WINDLASS/CAPSTANS	New England Trawler
STEERING SYSTEM	Paul Munroe
ANCHOR/CHAIN	Baldt
RADARS	Raytheon

FIGURE 2-2: ARS-50 CHARACTERISTICS AND FEATURES

2.1.2 The MCM ships will play a significant role during the second year of this Project (Phase II) in illustrating that the cost identification techniques developed during Phase I are not contract-specific. The assumptions made and procedures used for cost identification have been deliberately established so that they are not specific to any one contract or type of ship.

2.1.3 The YP boats are not involved in this Project, but are included here to provide some understanding of the total PBI contract workload during Phase I.

2.2 SHIPYARD BLAST/PAINT FACILITIES AND EQUIPMENT

2.2.1 PBI has one building containing both blasting and painting operations. The building is large enough to allow an assembly to be blasted and painted inside.

2.2.2- The shop blasting operation makes use of a blast media reclaimer with a water injection cooling system to provide maximum use of the recycled blast medium. Two 800 pound units are used to perform the. actual shop blasting operation. Blasting at the erection site is performed by portable 600 pound units using boiler slag as the abrasive.

2.2.3 The shop painting operation makes use-of six waterfalls and three gas fired makeup units. The shop is also equipped with a bake oven with a conveyor cart system capable of expediting drying time of each coat of paint. To aid in mixing the paints most often used at PBI, a plural component system is used with a 50:50 setup for plural component paints. Finally, a solvent reclaimer is used to reduce solvent cost. Most of the spraying in the shop and onboard ship is accomplished by airless and air-assisted airless sprayers with the exception of conventional equipment used for light viscosity paints.

2.3 GENERAL PAINTING PROCEDURE

2.3.1 Plate is received into the shipyard with a thin coat of shop primer. Once the plate takes the form of an assembly or panel, it is sweepblasted and sprayed with the first coat of the specified system. The entire exterior system is then applied if little or no hotwork remains, otherwise only the first primer coat is applied with the remainder of the system applied at the erection site. In the case of interior spaces, the assembly is moved to the erection site where the interior spaces receive their first finish coat as soon as the insulation (if installed) is in place. The assembly is then outfitted by the other trades. When completed, the final finish coat is applied. If necessary, repair work is performed on the coatings between the first and final finish coats.

2.4 PAINT DEPARTMENT LABOR CATEGORIES

2.4.1 The PBI Paint Department is broken down into two major categories, painters and cleaners. In general the painters are responsible for blasting, painting, taping, untaping, and. touchup; the cleaners are responsible for grinding rough edges (pr-ior to sweepblasting operations), cleaning prior to spraying operations, and for general cleaning in preparation for ship trials.

2.5 SPECIFIC PAINTING CONDITIONS ON ARS SHIPS

2.5.1 Compartment Complexity. In general the compartments on the ARS ships are small and densely outfitted. Few compartments span the width of the. ship. Figure 2-3 shows compartment surface areas broken down by compartment type.

2.5.2 Coating System. Virtually all steel on the ARS was coated with Pro-Line Paint Company preconstruction primer #4032 except for some key areas where inorganic zinc was used. This was generally followed in all areas by two coats of Pro-Line 5000 series polyamide epoxy. Exceptions to this procedure were minor, such as behind insulation, areas under floor coverings, etc. Top coats were generally as specified by the Navy, for example: on the underwater hull two coats of vinyl antifouling paint were used; the boot top area and external vertical surfaces were overcoated with silicon alkyd; and the interior spaces were overcoated with Navy specified top coats, the predominant requirement being two coats of chlorinated alkyd with respect to bulkheads and overheads, and enamels for decks. Small parts were also coated with typical Navy paint systems.

3.0 PAINTING COSTS IDENTIFIED

3.1 COST IDENTIFICATION SIGNIFICANCE

3.1.1 Before any type of corrective cost saving measure can take place, the cost of each identifiable operation must be determined. Such data will support an evaluation of which areas, and in what priority, should be examined further.

In the book, "Toyota Production System", by Yasuhiro Monden, the Author speaks of the importance of improving manual operations. He discusses a technique that categorizes all manual operations into one of three different headings. The three classifications are:

Pure Waste. Action altogether unnecessary that should be eliminated immediately, i.e., waiting time, stacking of intermediate products, and "double transfer".

Operations without "value added". Operations that are essentially wasteful but may be necessary under present operating procedures. These include walking long distances to pick up parts, unpacking vendor parcels, shifting a tool from one hand to the other, etc.

Value-added operations. Conversion or processing operations that increase t-he value of raw materials or semi-finished products by adding manual labor; i.e., assembly of parts, forging raw material tempering gears, painting bodywork, etc.

Mr. Monden says: "Net operations to increase value added typically constitute only a small portion of total operations, the large part of which serve only to increase costs. By raising the percentage of net operations to increase value added, labor required per unit can be reduced, thus reducing the number of workers at each workplace."

PETERSON BUILDERS, INC. - PAINT DEPT.

ARS Compartment Types and Their Respective Percents.

COMPARTMENT TYPE	TOTAL SQFT	PERCENT
Tanks	37366	24.6%
Machinery Spaces	22063	14.5%
Storerooms	20156	13.3%
Work Shops	19363	12.7%
Passages	12579	8.3%
Crew Berths	8053	5.3%
Lockers	6127	4.0%
Wet Spaces	5753	3.8%
Lounge & Recreation	4954	3.3%
Fan Rooms	4856	3.2%
Offices	4541	3.0%
Staterooms	2971	2.0%
Galley	1936	1.3%
Chill/Freeze Storage	1221	0.8%

FIGURE 2-3

This type of systematic breakdown analysis formed the basis for the cost identification process during Phase I. Once the problem has been identified, the resulting cost information can be used to support corrective actions through capital expenditures or procedural changes.

3.2 ARS TOTAL PAINTING COST VS. SHIP COST

During the construction of ARS-50, costs were collected for all labor and material associated with surface preparation and painting. These costs were compared with the costs for the SWBS groups 100-700. The results disclosed that 7.3% of the manhour and material cost of the ship could be attributed toward surface preparation and painting as shown by Figure 3-1. Contrary to assertions that suggest that painting related costs constitute 15% to 30% of the total ship cost, the painting cost data from the ARS-50 suggests a significantly lower percentage for the cost of painting a ship.

3.3 ARS PAINTING AND CLEANING LABOR VS. OTHER TRADES

3.3.1 In order to get an idea of how the Paint Department costs compared with other trades, the manhours for ARS-50 were totalled and summarized. As shown by Figure 3-2 and as expected, Hull, Piping, and Electrical ranked high in labor content. The fourth place rank of the painters and cleaners was somewhat unexpected, however. Their combined total turned out to be 12.9% of the total “touch-labor” manhours spent on ARS-50, suggesting that painting and cleaning is, indeed, a labor intensive effort relative to many other trades. .

3.4 ARS PAINTING AND CLEANING LABOR CONSTITUENTS

3.4.1 Although it may generally be felt that a Paint Department spends most of the time painting, this conclusion is far from the truth. There are many collateral activities that absorb most of the time. Figure 3-2, based on data from ARS-52 when 91% complete, shows that the actual laying of paint accounts for only about 15.3% of the total work by the Paint Department. A further breakdown of the rework segment of Figure 3-3 is shown by Figure 3-4. A comparable determination on ARS-50 as a completed ship showed actual laying of paint as about 23% of the total effort by the Paint Department. Consequently, since the purpose of this Project was to identify the true cost of painting operations, it was deemed necessary that these collateral duties be carefully identified.

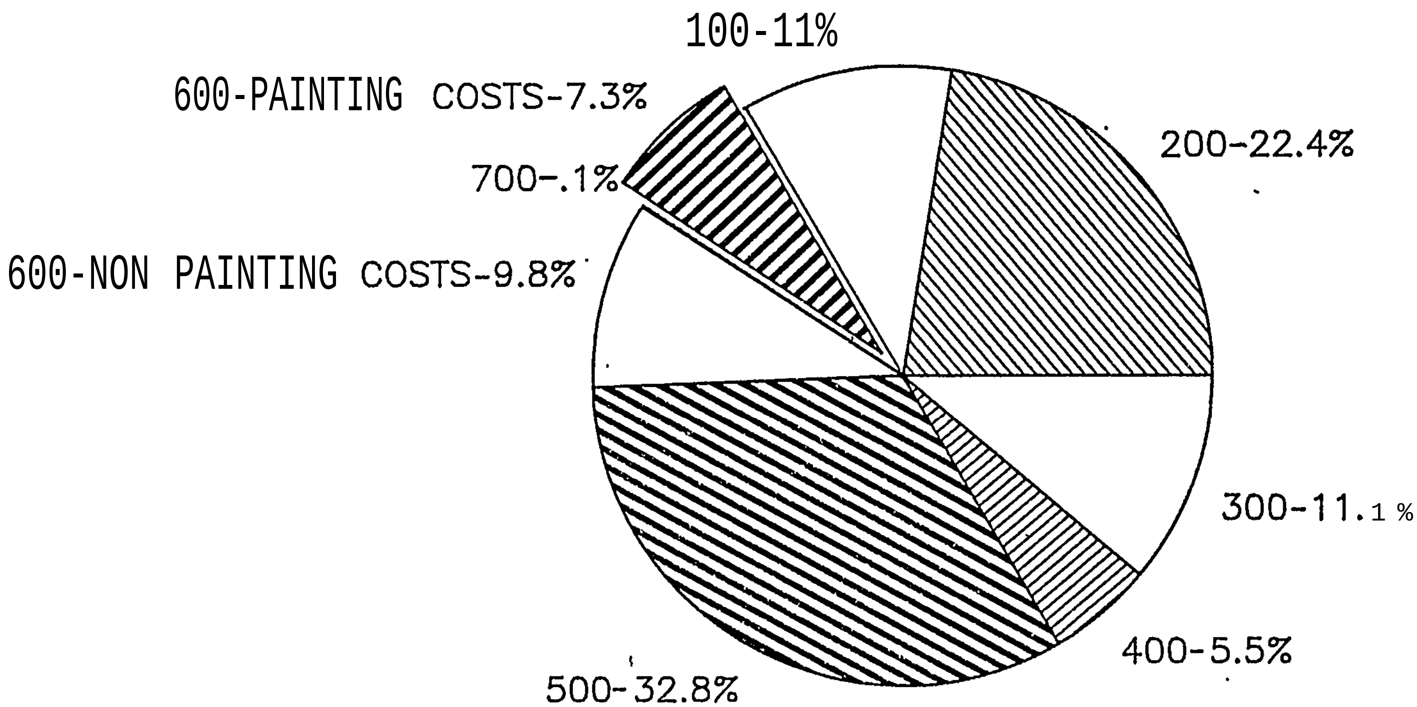
3.5 DATA COLLECTION AND ANALYSIS

3.5.1 Analysis of the different collateral computerized costs would be done on a percentage basis making use of the method espoused by Mr. Monden and described earlier. The data collection method involved gathering raw time data on each major operation. Randomly, the operations were watched and times collected. The collected data was entered into a computerized spreadsheet program which generated percentages for each collateral activity. After several weeks of data collection, the operation percentages began to stabilize until finally an acceptable average was established. Figure 3-5 provides an example of the data analysis related to grinding.

3.5.2 The painting operation at PBI can be broken down into two major categories; painting in the shop, and painting onboard ship. Shop painting

ARS-50 MATERIAL AND MANHOUR BREAKDOWN VS PAINTING COSTS

(SWBS 100- 700 GROUP)



100- HULL STRUCTURE	500 - AUXILIARY SYSTEMS
200 - PROPULSION PLANT	600 - OUTFIT & FURNISHINGS
300- ELECTRIC PLANT	700 - ARMAMENT
400 - COMMAND & SURVEILLANCE	

FIGURE 3-1

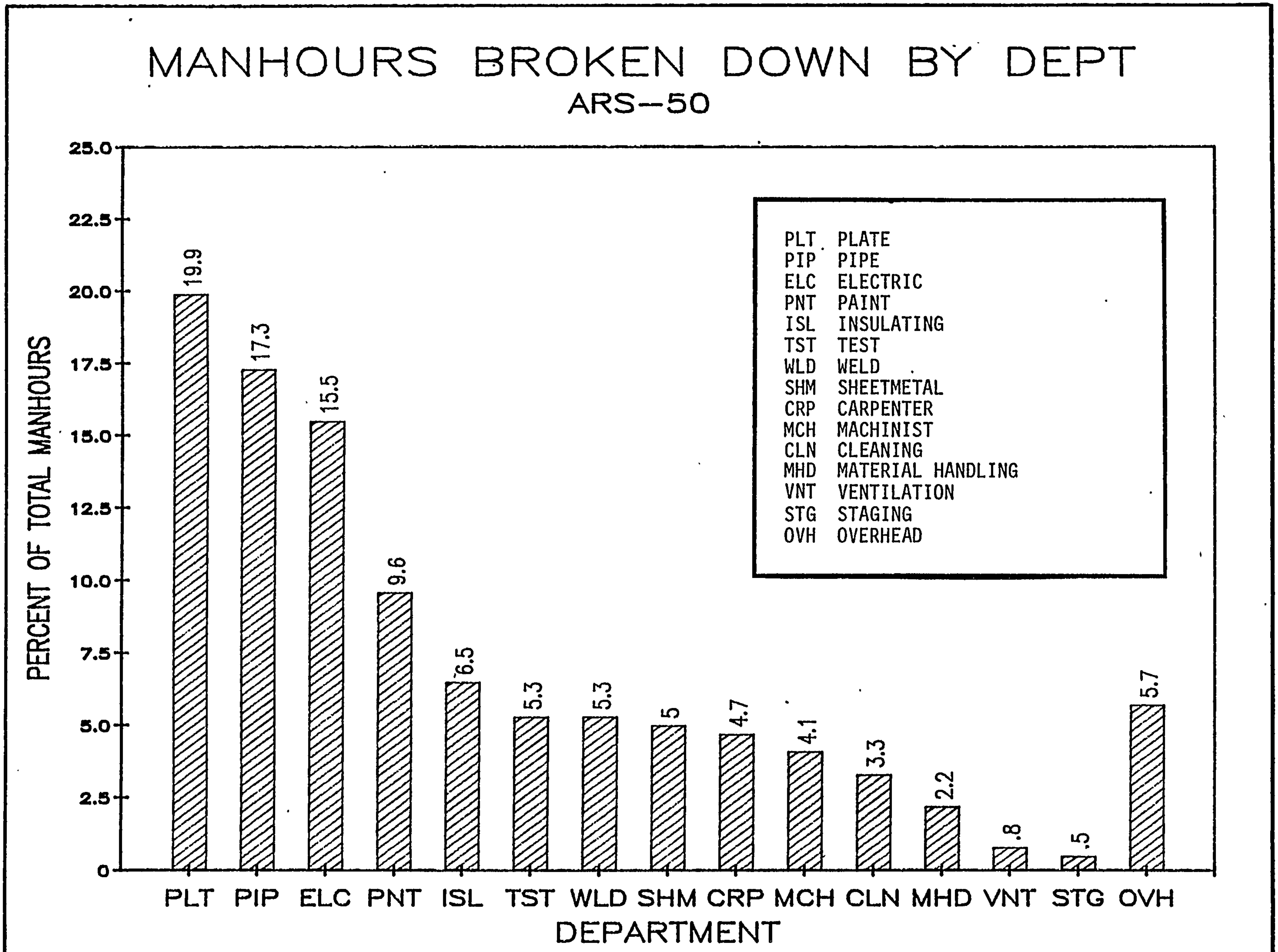

MANHOURS BROKEN DOWN BY DEPT
ARS-50
PERCENT OF TOTAL MANHOURS
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
19.9
17.3
15.5
9.6
6.5
5.3
5.3
5
4.7
4.1
3.3
2.2
.8
.5
5.7
PLT PIP ELC PNT ISL TST WLD SHM CRP MCH CLN MHD VNT STG OVH
DEPARTMENT
PLT PLATE
PIP PIPE
ELC ELECTRIC
PNT PAINT
ISL INSULATING
TST TEST
WLD WELD
SHM SHEETMETAL
CRP CARPENTER
MCH MACHINIST
CLN CLEANING
MHD MATERIAL HANDLING
VNT VENTILATION
STG STAGING
OVH OVERHEAD

FIGURE 3-2

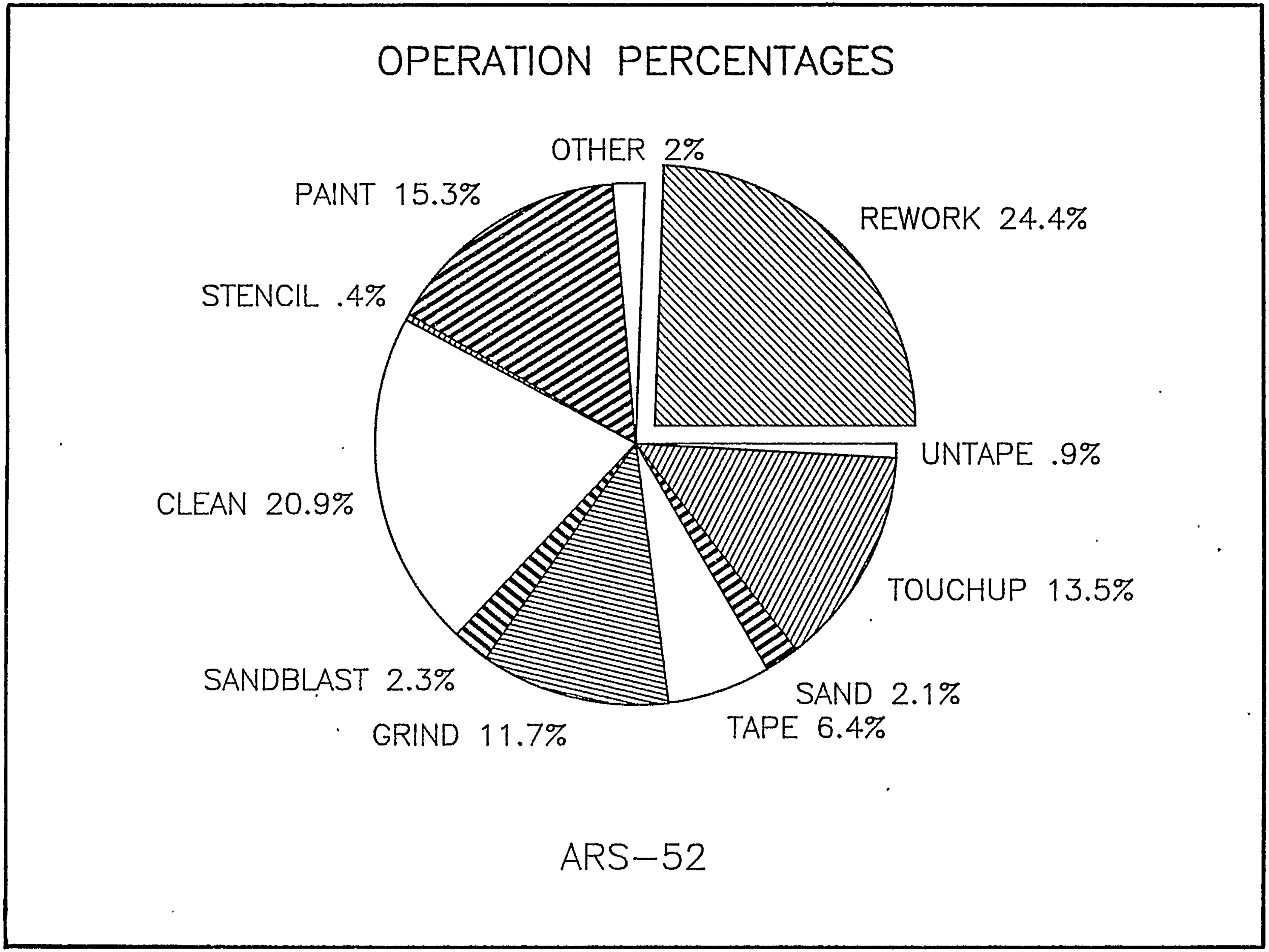

OPERATION PERCENTAGES
OTHER 2%
PAINT 15.3%
REWORK 24.4%
STENCIL .4%
UNTAPE .9%
CLEAN 20.9%
TOUCHUP 13.5%
SANDBLAST 2.3%
SAND 2.1%
GRIND 11.7%
TAPE 6.4%
ARS-52

FIGURE 3-3

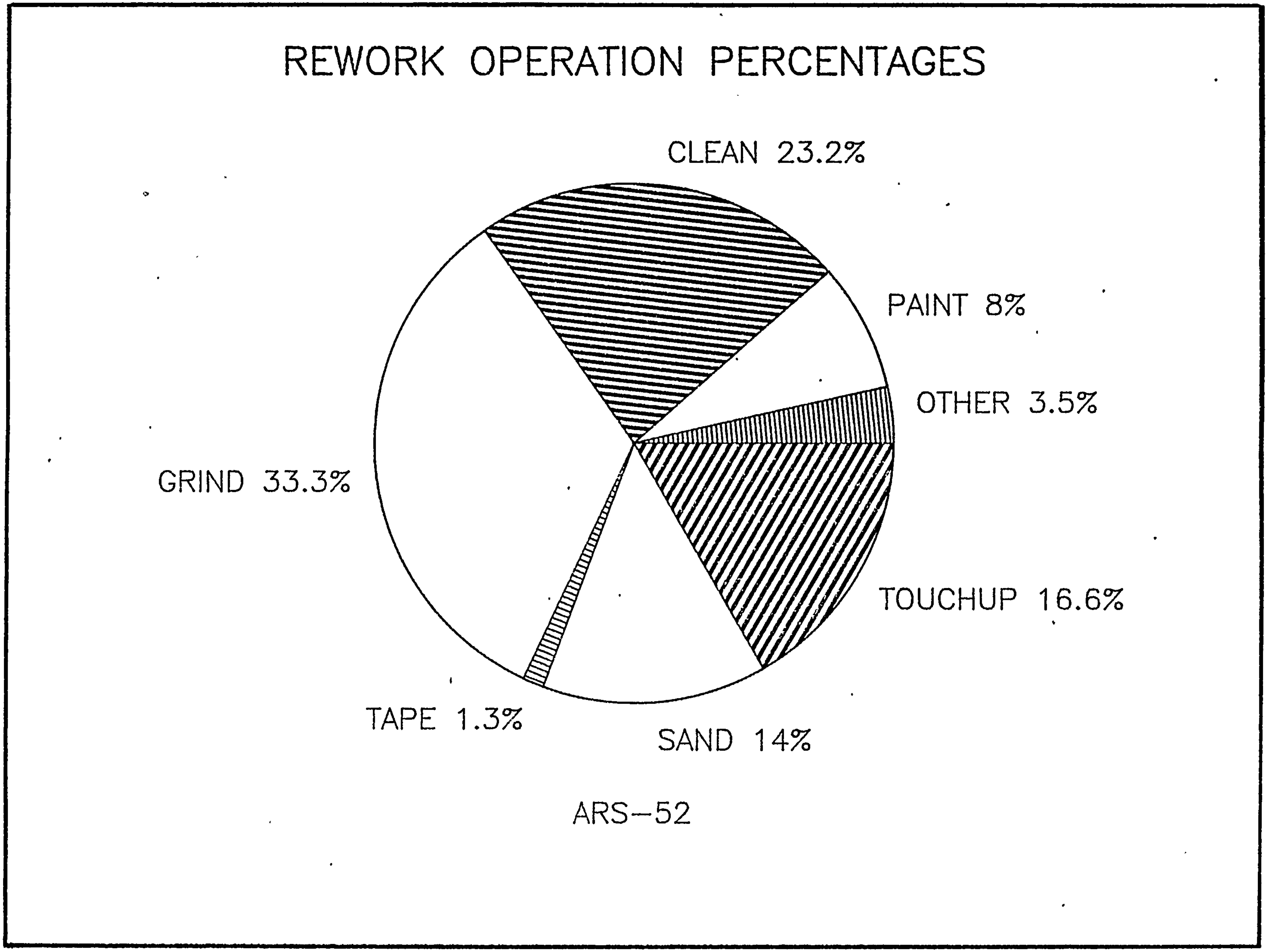

REWORK OPERATION PERCENTAGES
CLEAN 23.2%
PAINT 8%
OTHER 3.5%
TOUCHUP 16.6%
SAND 14%
TAPE 1.3%
GRIND 33.3%
ARS-52

FIGURE 3-4

GRINDING DATA SURVEY SHEET

DEPARTMENT BEING STUDIED: PAINT DEPT.

26-Feb-86

% of Total Observ's	Row Totals (minutes)		DAILY SEPT 21 PIV,POV = 71 21 PRD,PED = 1 6 MIN	%O	MINUTES OF ACTIVITY PERFORMED	DAILY SEPT 25 PIV,POV = 35 51 PRD,PED = 0 0 MIN	%O	MINUTES OF ACTIVITY PERFORMED
		PROCESS WITH VALUE ADDED % 42.4						
42.4	337	POWER TOOL CLEANING	77	71	5 8 5 3 30 9 7 2 7 1	28	35	2 4 2 1 1 1 1 8 2 6
0.0	0		0	0		0	0	
		PROCESS WITHOUT VALUE ADDED % 40.8						
8.7	69	CHANGING TOOLS	14	13	3 4 2 1 2 1 1	10	12	1 9
10.3	82	INSPECTING AND SEARCHING	1	1	1	3	4	2 1
9.6	76	MOVING MATERIALS AND EQUIPMENT	1	1	1	13	16	2 2 1 1 1 3 1 1 1
10.2	81	GETTING TOOLS AND MATERIAL	2	2	2	15	19	1 6 1 1 6
2.0	16	SETUP PERSONAL PROTECTIVE EQUIPMENT	5	5	3 2	0	0	
0.0	0		0	0		0	0	
		PROCESS DELAY % 2.39						
0.6	5	RECEIVING INSTRUCTIONS	1	1	1	0	0	
1.8	14	WAITING FOR TOOL AND MATERIALS	0	0		12	15	12
0.0	0		0	0		0	0	
		PERSONAL DELAY % 14.4						
14.4	114	PERSONAL FATIQUE/BREAK	7	6	3 1 1 2	0	0	
0.0	0		0	0		0	0	

column totals 794

Five additional days of data not shown.

FIGURE 3-5: GRINDING DATA ANALYSIS

activities consist of spraying sections, panels, and small parts. Where possible the small parts are coated with the entire coating system. Figure 3-6 shows the percentages associated with the spraying of small parts. Onboard activities were also examined. Significant differences can be seen between painting in the shop and painting onboard ship. The fact that the collateral activities increased for onboard painting, as shown by comparing Figure 3-6 and Figure 3-7, illustrates that the painting operation onboard ship is less efficient than painting in the shop.

3.5.3 An analysis was performed for each major operation. .Figures 3-8, 3-9, and 3-10 show the breakdown of grinding, taping, and untaping operations, respectively.

3.6 ARS MATERIAL COST BREAKDOWN - PAINTING VS. OTHERS

3.6.1 Since the Paint Department accounts for almost 13% of the total labor, the question still remains as to why it contributes only 7.3%. of the total ship cost. The answer probably lies in the fact that the cost of the materials used by the painters is quite small when compared to the cost of the materials used by other trades. Figure 3-11 shows the breakdown of material costs for the ARS contract by SWBS grouping. (Note that PBI uses an independent design agent, consequently in this chart the subcontracted engineering services show as purchased materials and equipment.)

3.6.2 Although the material cost with respect to the Paint Department is fairly insignificant, it is interesting to see what makes up this material cost. As shown by Figure 3-12, almost 63% of the Paint Department material cost resulted from the purchase of paint. This situation was expected, because paint is the only product that the painters actually add to the ship.

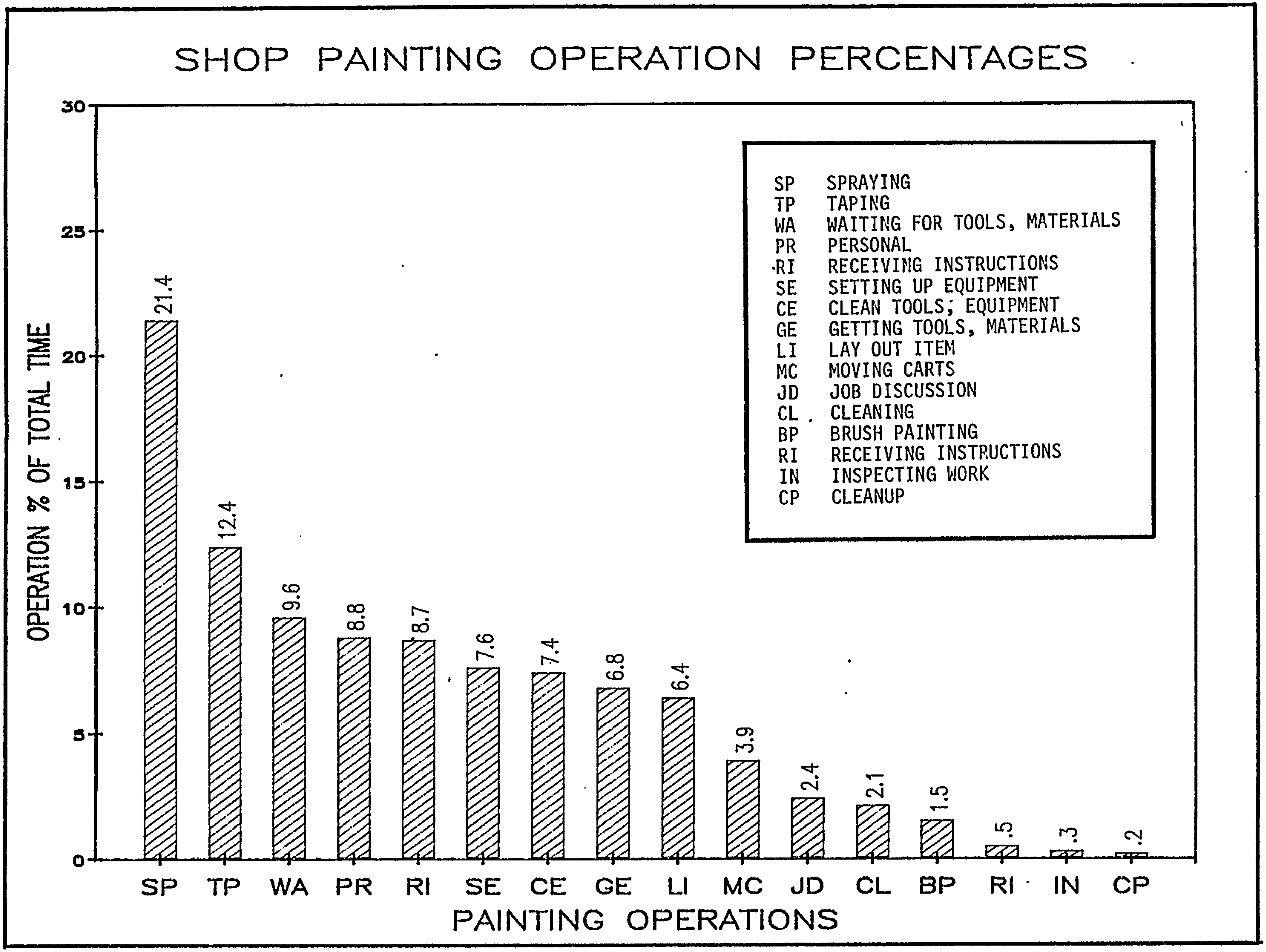
3.6.3 The Paint Department material cost is also quite small when compared to the Paint Department labor. Materials constitute only 26.1% of the total Paint Department costs, as shown by Figure 3-13.

3.6.4 Summarizing the findings above, it seems evident that Paint Department labor can be a significant portion of the total labor needed to build a ship. On the other hand, the cost of materials used by the Paint Department appears to be almost negligible when compared to the cost of material used by other trades. This also tends to argue that the control of Paint Department labor is much more important than spending a great deal of effort shopping for the cheapest materials.

4.0 PAINT DEPARTMENT COSTS RELATIVE TO PRE-OUTFITTING

4..1 GENERAL DISCUSSION

4.1.1 Based on the preliminary data analysis of labor operations and their respective percentages of the Paint Department manhours, it was decided that the rework due to the repair of damaged painted surfaces should be analyzed further. According to data from ARS-50 and ARS-51, the Paint Department spent about 16% of the-manhours performing this type of rework activity. The majority of these manhours were considered rework because they involved the repair of coatings damaged by hotwork. This type of



SHOP PAINTING OPERATION PERCENTAGES
OPERATION % OF TOTAL TIME
0
5
10
15
20
25
30
21.4
12.4
9.6
8.8
8.7
7.6
7.4
6.8
6.4
3.9
2.4
2.1
1.5
.5
.3
.2
SP TP WA PR RI SE CE GE LI MC JD CL BP RI IN CP
PAINTING OPERATIONS
SP SPRAYING
TP TAPING
WA WAITING FOR TOOLS, MATERIALS
PR PERSONAL
RI RECEIVING INSTRUCTIONS
SE SETTING UP EQUIPMENT
CE CLEAN TOOLS; EQUIPMENT
GE GETTING TOOLS, MATERIALS
LI LAY OUT ITEM
MC MOVING CARTS
JD JOB DISCUSSION
CL CLEANING
BP BRUSH PAINTING
RI RECEIVING INSTRUCTIONS
IN INSPECTING WORK
CP CLEANUP

FIGURE 3-6

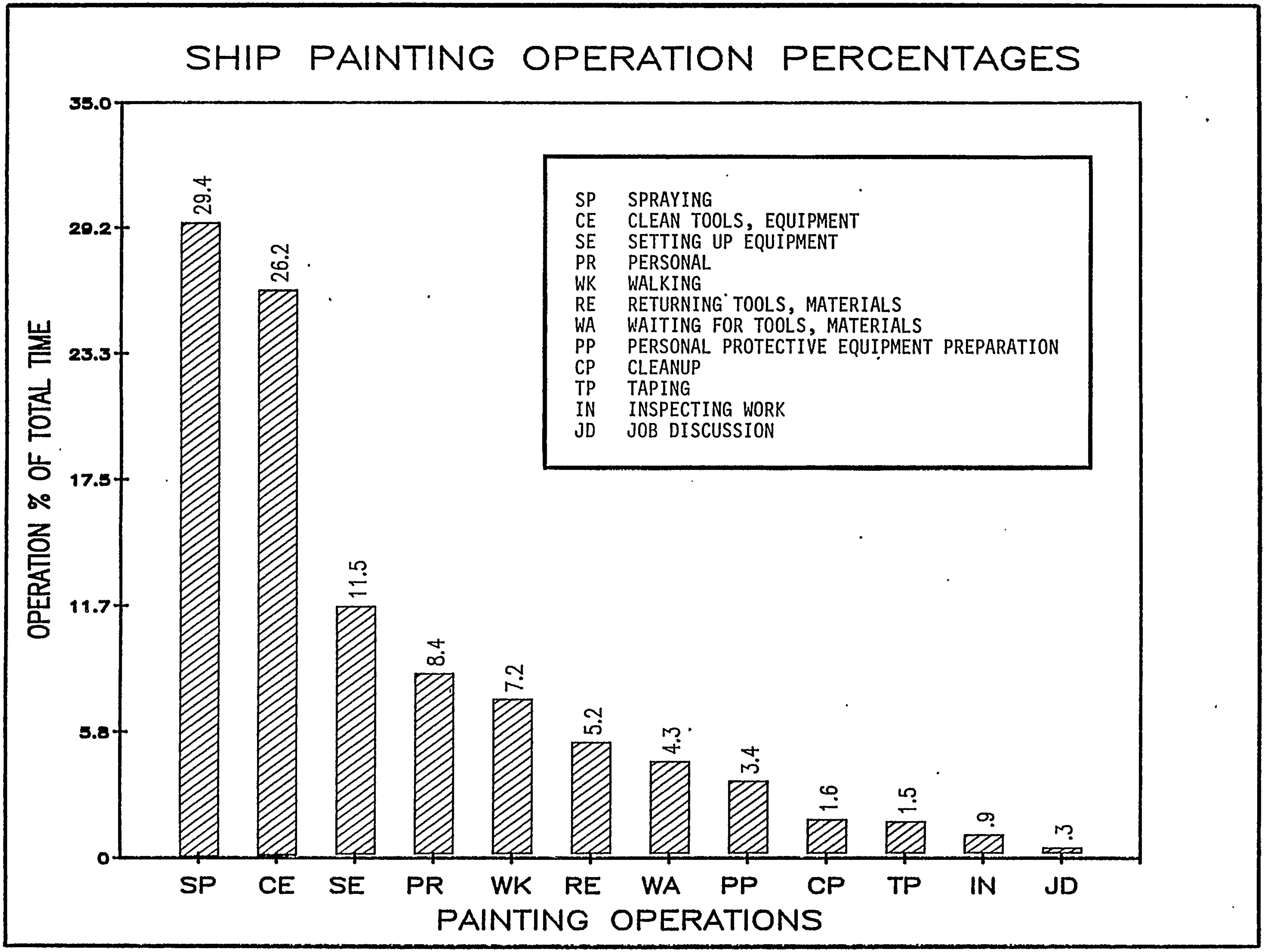

SHIP PAINTING OPERATION PERCENTAGES
OPERATION % OF TOTAL TIME
35.0
29.2
23.3
17.5
11.7
5.8
0
29.4
26.2
11.5
8.4
7.2
5.2
4.3
3.4
1.6
1.5
.9
.3
SP SPRAYING
CE CLEAN TOOLS, EQUIPMENT
SE SETTING UP EQUIPMENT
PR PERSONAL
WK WALKING
RE RETURNING TOOLS, MATERIALS
WA WAITING FOR TOOLS, MATERIALS
PP PERSONAL PROTECTIVE EQUIPMENT PREPARATION
CP CLEANUP
TP TAPING
IN INSPECTING WORK
JD JOB DISCUSSION
SP
CE
SE
PR
WK
RE
WA
PP
CP
TP
IN
JD
PAINTING OPERATIONS

FIGURE 3-7

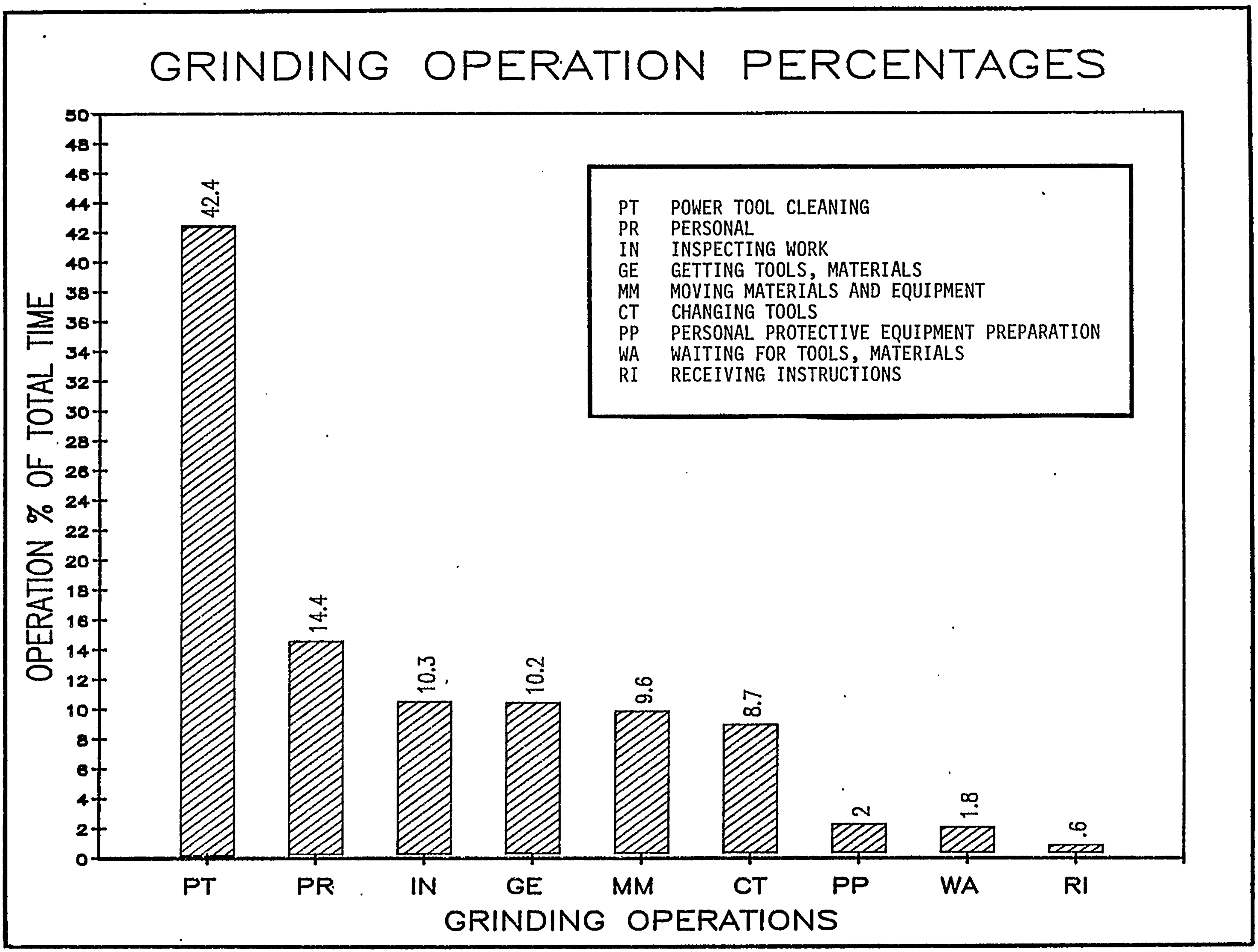
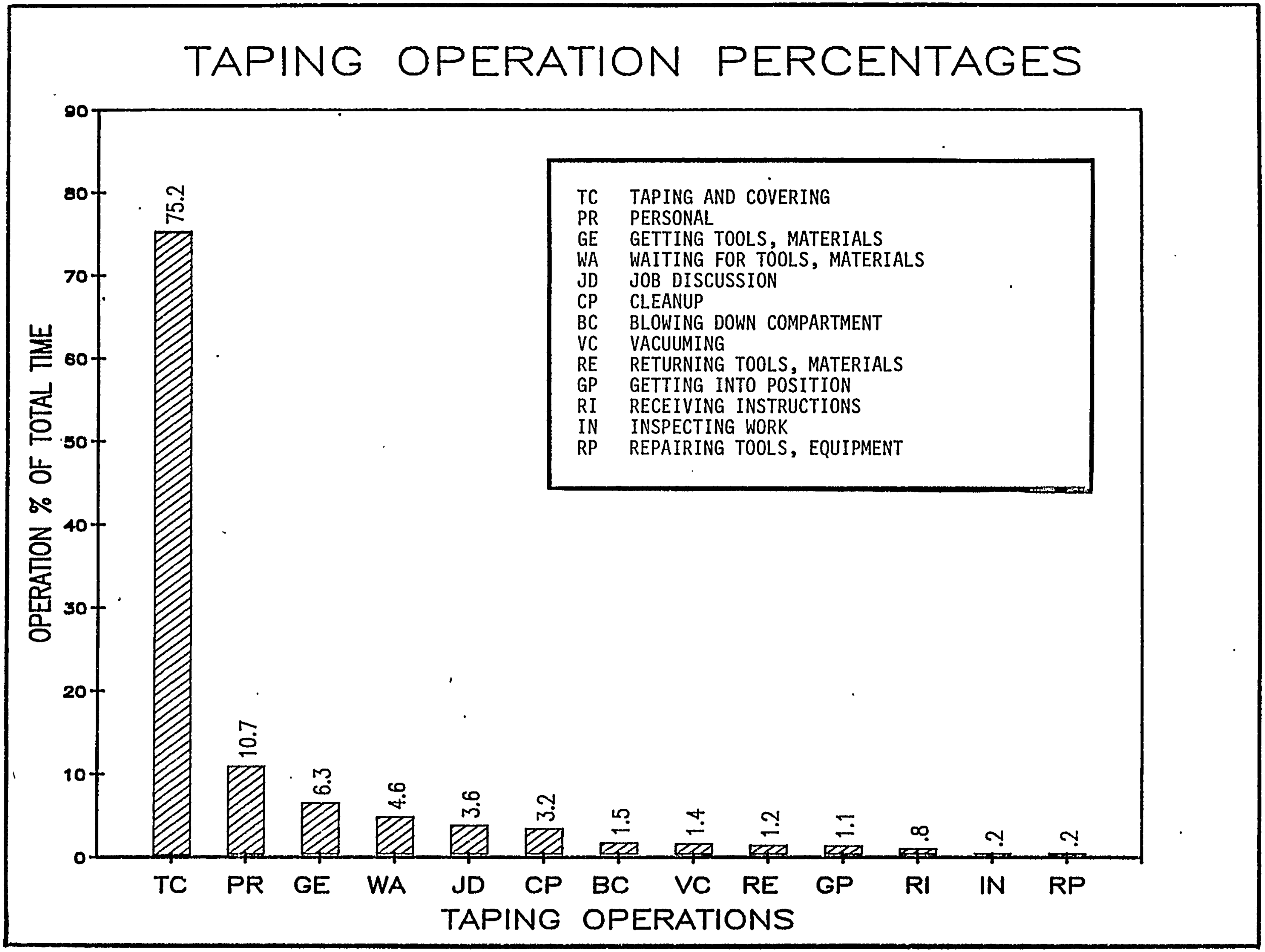

GRINDING OPERATION PERCENTAGES
OPERATION % OF TOTAL TIME
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
PT POWER TOOL CLEANING
PR PERSONAL
IN INSPECTING WORK
GE GETTING TOOLS, MATERIALS
MM MOVING MATERIALS AND EQUIPMENT
CT CHANGING TOOLS
PP PERSONAL PROTECTIVE EQUIPMENT PREPARATION
WA WAITING FOR TOOLS, MATERIALS
RI RECEIVING INSTRUCTIONS
42.4
14.4
10.3
10.2
9.6
8.7
2
1.8
.6
PT
PR
IN
GE
MM
CT
PP
WA
RI
GRINDING OPERATIONS

FIGURE 3-8



TAPING OPERATION PERCENTAGES
OPERATION % OF TOTAL TIME
90
80
70
60
50
40
30
20
10
0
75.2
10.7
6.3
4.6
3.6
3.2
1.5
1.4
1.2
1.1
.8
.2
.2
TC TAPING AND COVERING
PR PERSONAL
GE GETTING TOOLS, MATERIALS
WA WAITING FOR TOOLS, MATERIALS
JD JOB DISCUSSION
CP CLEANUP
BC BLOWING DOWN COMPARTMENT
VC VACUUMING
RE RETURNING TOOLS, MATERIALS
GP GETTING INTO POSITION
RI RECEIVING INSTRUCTIONS
IN INSPECTING WORK
RP REPAIRING TOOLS, EQUIPMENT
TC PR GE WA JD CP BC VC RE GP RI IN RP
TAPING OPERATIONS

FIGURE 3-9

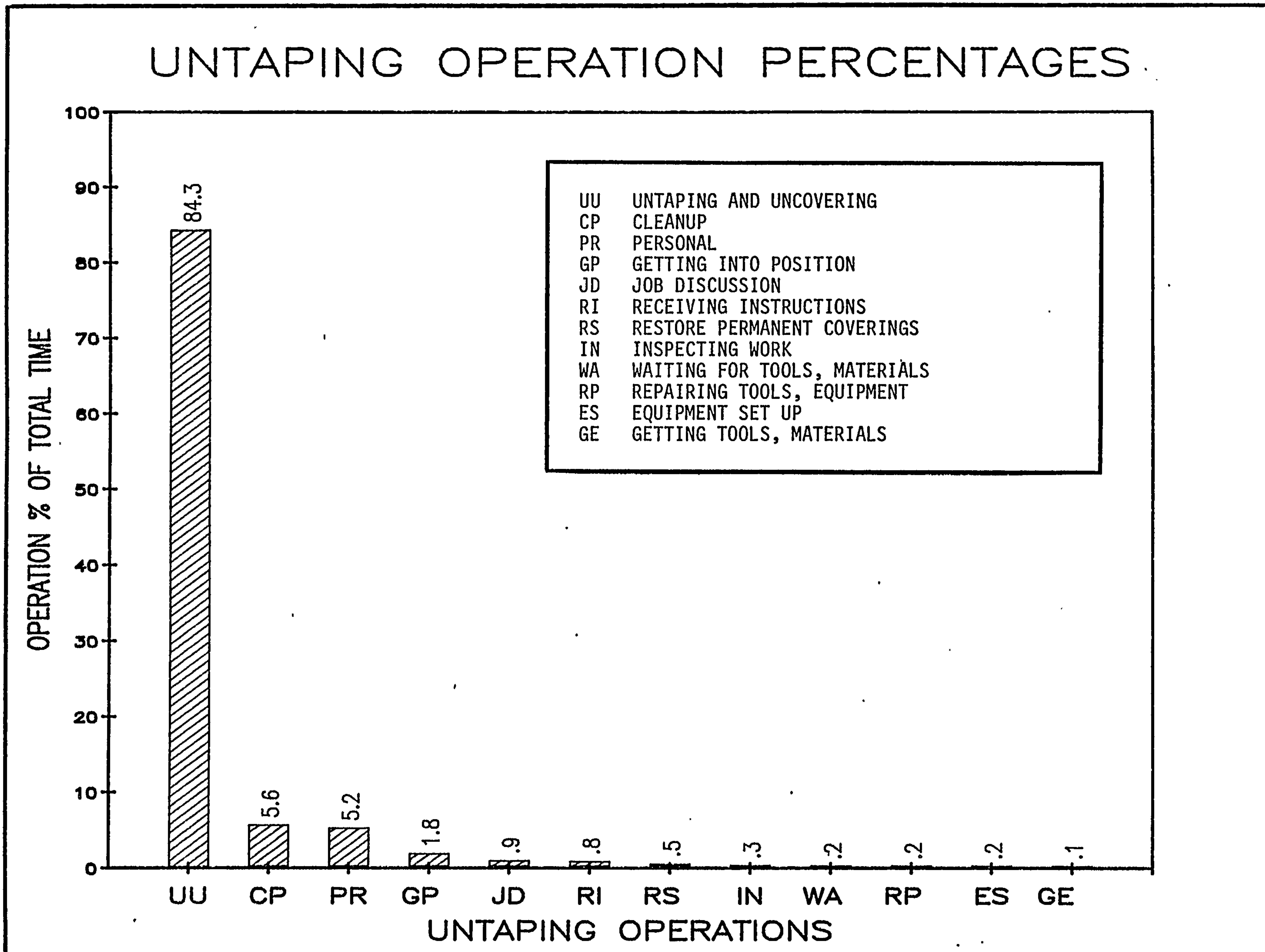

UNTAPING OPERATION PERCENTAGES
OPERATION % OF TOTAL TIME
100
90
80
70
60
50
40
30
20
10
0
84.3
5.6
5.2
1.8
.9
.8
.5
.3
.2
.2
.2
.1
UU UNTAPING AND UNCOVERING
CP CLEANUP
PR PERSONAL
GP GETTING INTO POSITION
JD JOB DISCUSSION
RI RECEIVING INSTRUCTIONS
RS RESTORE PERMANENT COVERINGS
IN INSPECTING WORK
WA WAITING FOR TOOLS, MATERIALS
RP REPAIRING TOOLS, EQUIPMENT
ES EQUIPMENT SET UP
GE GETTING TOOLS, MATERIALS
UU CP PR GP JD RI RS IN WA RP ES GE
UNTAPING OPERATIONS

FIGURE 3-10

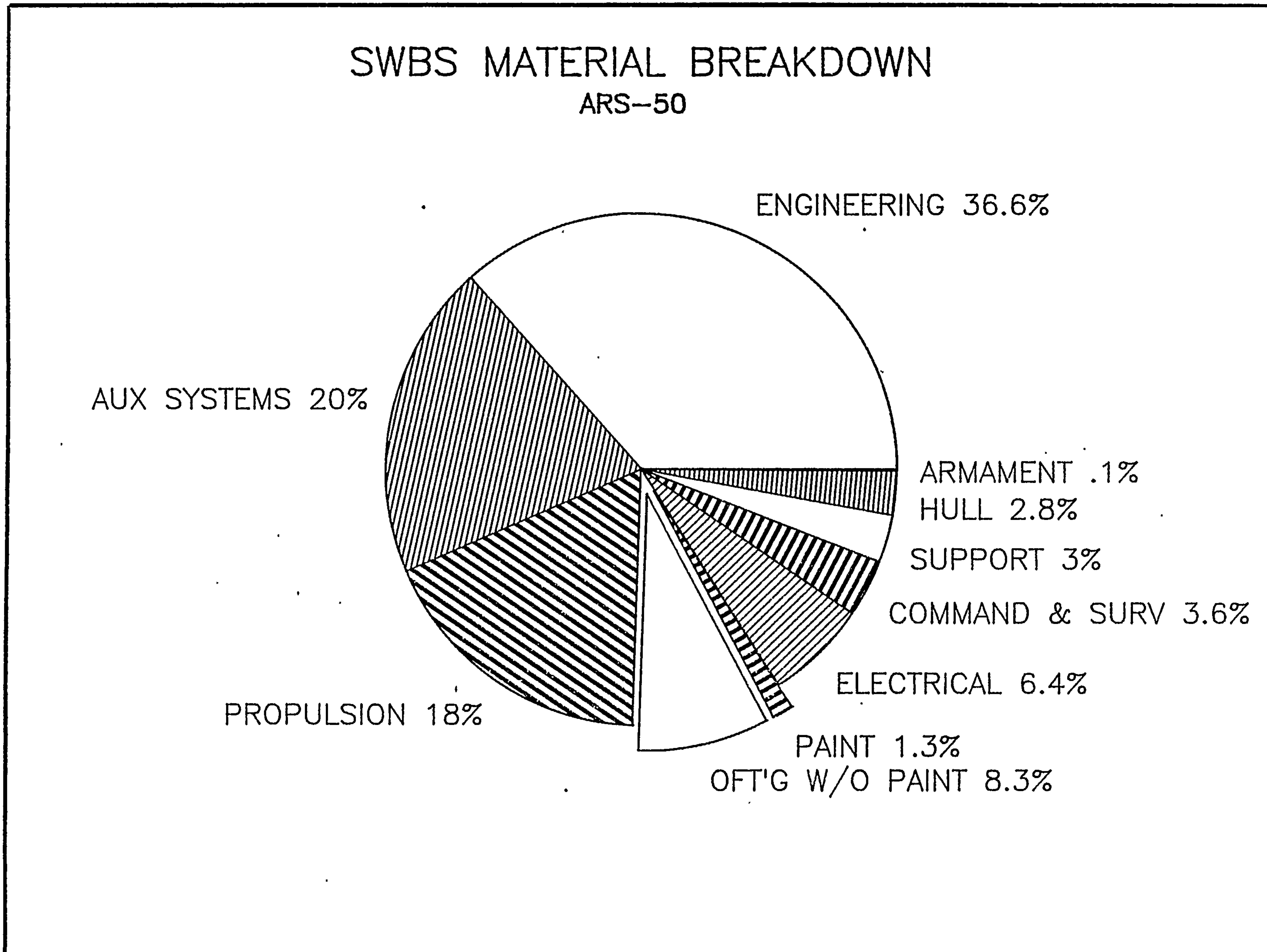

SWBS MATERIAL BREAKDOWN
ARS-50
ENGINEERING 36.6%
AUX SYSTEMS 20%
ARMAMENT .1%
HULL 2.8%
SUPPORT 3%
COMMAND & SURV 3.6%
ELECTRICAL 6.4%
PROPULSION 18%
PAINT 1.3%
OFT'G W/O PAINT 8.3%

FIGURE 3-11

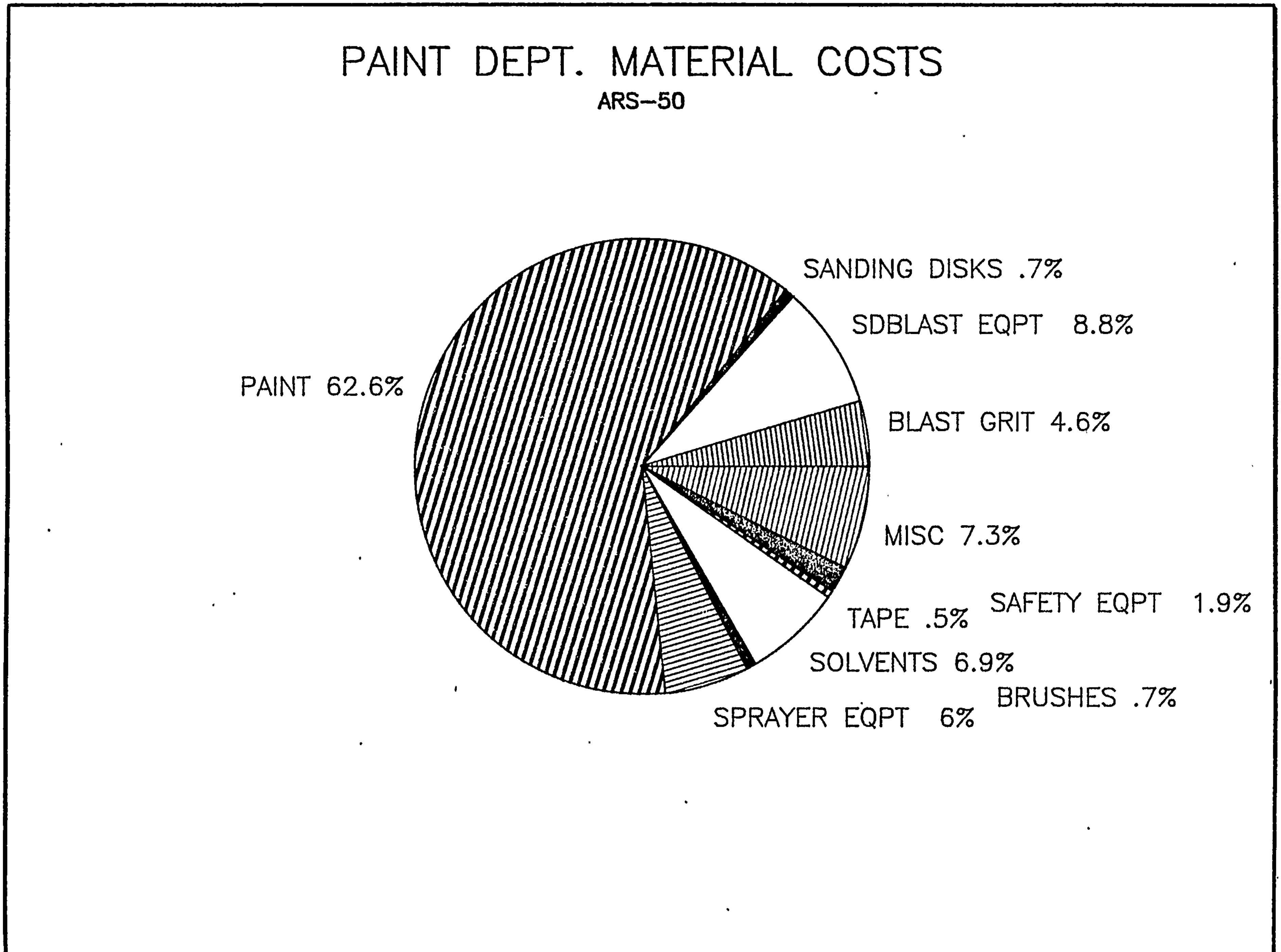

PAINT DEPT. MATERIAL COSTS
ARS-50
SANDING DISKS .7%
SDBLAST EQPT 8.8%
PAINT 62.6%
BLAST GRIT 4.6%
MISC 7.3%
SAFETY EQPT 1.9%
TAPE .5%
SOLVENTS 6.9%
BRUSHES .7%
SPRAYER EQPT 6%

FIGURE 3-12

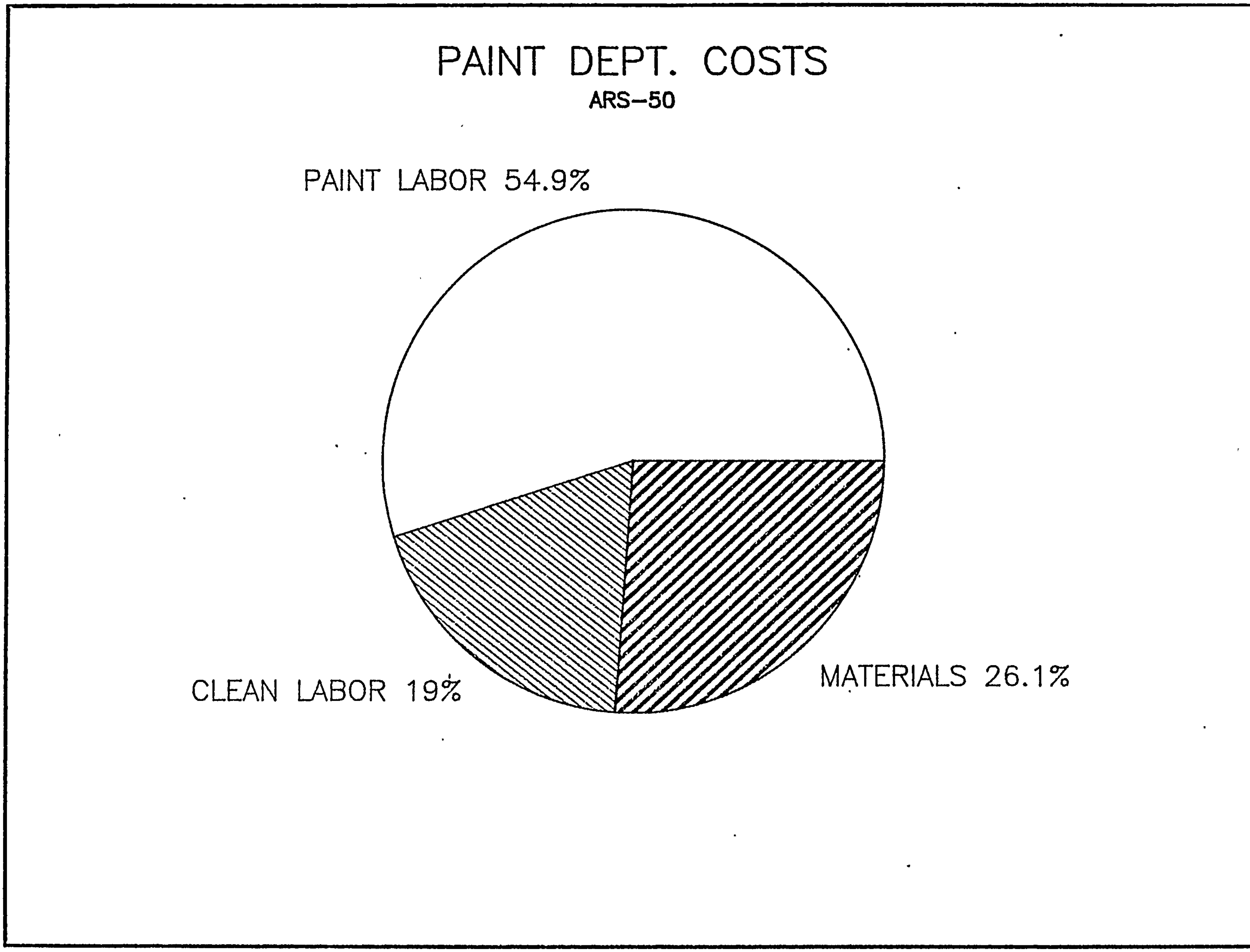

PAINT DEPT. COSTS
ARS-50
PAINT LABOR 54.9%
CLEAN LABOR 19%
MATERIALS 26.1%

FIGURE 3-13

rework would not have been encountered had the items been installed prior to blasting and applying the first primer coat.

4.1.2 In a NSRP report authored by Mr. John Peart entitled, "A Descriptive Overview of Japanese Shipbuilding Surface Preparation and Coating Methods", Mr. Peart describes the attitude of Japanese shipbuilders toward avoiding rework. In general, it is suggested that the Japanese feel so strongly about avoiding rework that no effort will be spared to avoid damage, material loss, and consequent time loss during repair *or* replacement work. "The most ABSOLUTE law in the Japanese manufacturing system is NO REWORK, as reworking has such a negative impact on productivity".

4.1.3 In another report sponsored by the National Shipbuilding Research Program (NSPR), the author discusses the highly successful Zone Painting Method (ZPTM) used by Japanese shipbuilders. He cites three prerequisites for the successful implementation of ZPTM. The first and third prerequisites deal with painting interval durations and the use of shop primers, both of which are important. The most important, however, with regard to the point being addressed here is the second prerequisite, "Each hull block should be virtually finished in order to minimize surface preparation and painting rework caused by further cutting, fitting, or welding".

4.1.4 The two statements cited above were substantiated and quantified by this study. Hence, any doubts or uncertainty concerning the value of "zone outfitting" techniques and the positive impact of this technology on surface preparation and painting costs should be allayed by the results of this study.

4.2 REWORK INVESTIGATED

4.2.1 The first operation in the rework process is grinding. It is performed on all areas that are burned, have rusted, or have weld splatter deposits on them. The grinding operation is usually performed with a disk grinder, a router, or a steel wire brush. Cleaning is the next operation, and it involves wiping smoke and dirt off the surface prior to the application of paint. Usually a liquid cleaner is used to speed up the operation. Finally, the touchup operation is performed, consisting of replacing the damaged coats of paint. The touchup operation is carried out by using a small cup gun, a clobber, a roller, or a brush. This operation may involve several coats of paint depending upon how many coats were damaged. .

4.2.2 In order to further identify the causes of the hotwork that required the touchup, a list was generated containing the hotwork items most responsible for the touchup rework. This information came from discussions with the painters who were well acquainted with the circumstances that produce the rework. The list.is provided as Figure 4-1.

4.2.3 Since not-all touchup is considered rework, a distinction had to be made between necessary touchup and unnecessary touchup. Necessary touchup is the type of work that cannot be performed before the section or panel has

IDENTIFIED HOT WORK ITEMS

DUCWORK HANGERS

DUCTWORK PENETRATIONS

STRUCTURAL COMPENSATION RINGS

FOUNDATIONS

LIGHT FIXTURE HANGERS

PIPE HANGERS

PIPE PENETRATIONS

sTUDS

WIRE HANGERS

FIGURE 4-1

gone through the blast and paint shop. As an example, there is no alternative to the hotwork caused by key section joining welds which must be performed at the erection site. Unnecessary touchup is the type of work that could have been avoided if the hotwork had been performed before the. section or panel had gone through the blast and paint shop, thereby eliminating the reason for additional grinding and touchup. Clearly, it makes good sense to accomplish the hotwork before shop painting, so that these rework manhours are eliminated. Of the entire amount of hotwork performed, only 7.2% is classified as necessary and so must be performed at the erection site. The remaining hotwork is classified as unnecessary, which means that if the section or panel is properly outfitted at the designated time, then the hotwork will not generate additional Paint Department rework.

4.3 REWORK (TOUCHUP) DATA COLLECTION

4.3.1 Once the hotwork items were identified, a data collection scheme was developed, consisting of gathering times for the three operations in question; grinding, cleaning, and touchup. Times were collected for each operation and. for each hotwork item. The collateral costs were also identified. The resulting data were then entered into a spreadsheet analysis program, which allocated the proper percentages for each major operation and for the associated secondary operations. Results are shown by Figure 4-2 and 3-7.

4.4 REWORK (TOUCHUP) ESTIMATING FORMULA DEVELOPMENT

4.4.1 The rework data described above were then used to develop estimating formulas. Both simple averaging and regression analysis techniques were used. For example, the touchup of small foundations less than 2" in diameter could be estimated by simple averaging of the data. Figure 4-3 shows this situation. On the other hand, touchup of pipe penetrations was found to be directly related to the number of lineal inches of weld, and therefore regression analysis was needed to develop an estimating formula. Figure 4-4 shows this formula.

4.4.2 A program was then developed that would handle the many formulas and yield predicted painting costs relative to the lack of pre-outfitting. Figure 4-5 provides an example of the program format. To invoke the formulas into the program, the user first enters the total amount of hotwork for each category. Then the user enters partial hotwork performed (if appropriate). Once this information is entered, the program calculates the time estimates, including the. time for collateral activities. Next the program totals the estimates for each type of hotwork item. A grand total is then calculated, and further identified as to how much is necessary rework and how much is unnecessary rework.

4.5 ESTIMATING FORMULAS APPLIED

4.5.1 several tests were run using the estimating formula program. In particular, a test was performed on section 601 for the ARS-52. Upon completion of blasting and painting of the section in the shop, an inventory of hotwork completed was taken. The hotwork items that had already been installed were compared with the total hotwork identified from

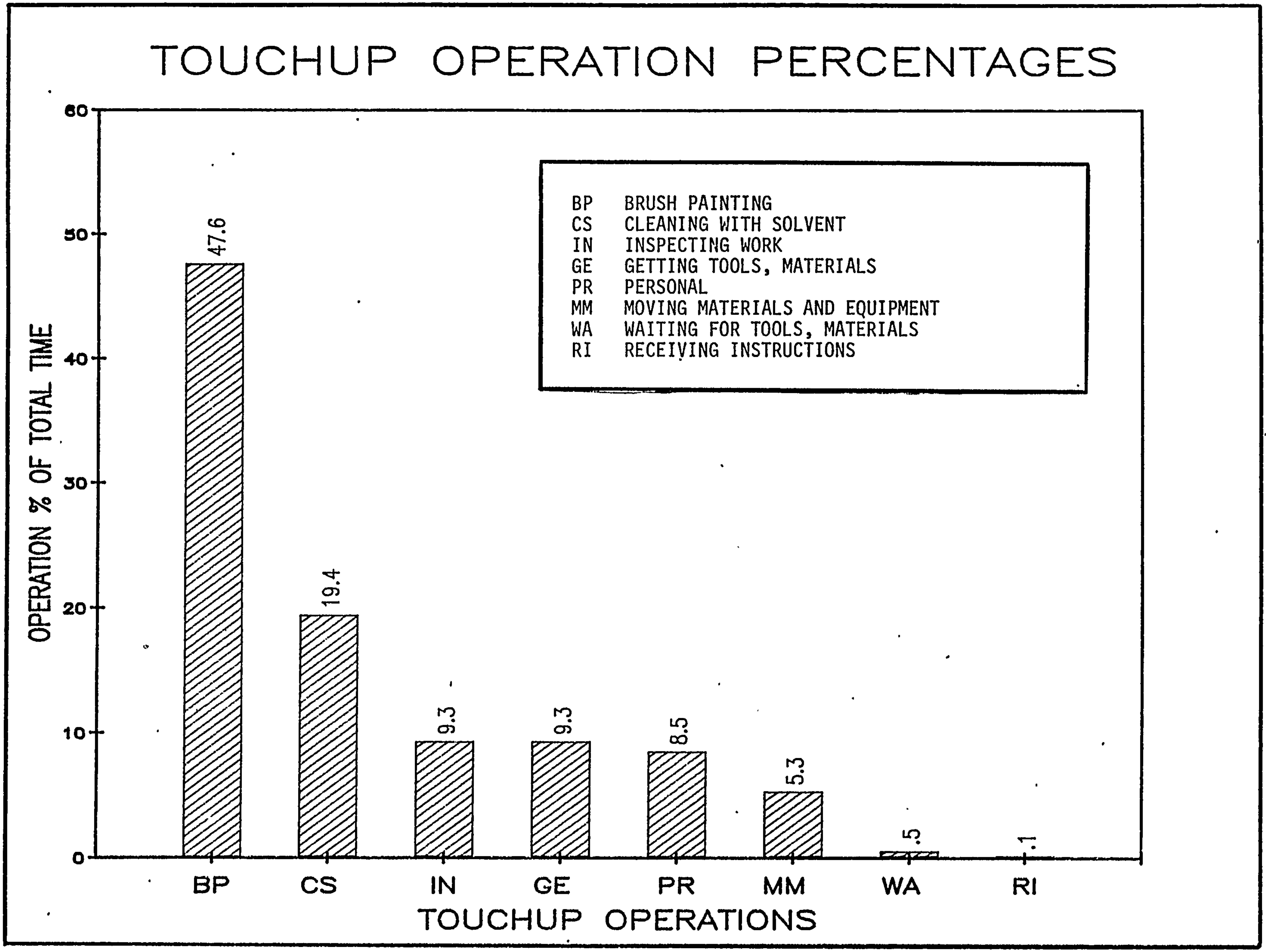

TOUCHUP OPERATION PERCENTAGES
OPERATION % OF TOTAL TIME
0
10
20
30
40
50
60
47.6
19.4
9.3
9.3
8.5
5.3
.5
.1
BP BRUSH PAINTING
CS CLEANING WITH SOLVENT
IN INSPECTING WORK
GE GETTING TOOLS, MATERIALS
PR PERSONAL
MM MOVING MATERIALS AND EQUIPMENT
WA WAITING FOR TOOLS, MATERIALS
RI RECEIVING INSTRUCTIONS
BP
CS
IN
GE
PR
MM
WA
RI
TOUCHUP OPERATIONS

FIGURE 4-2

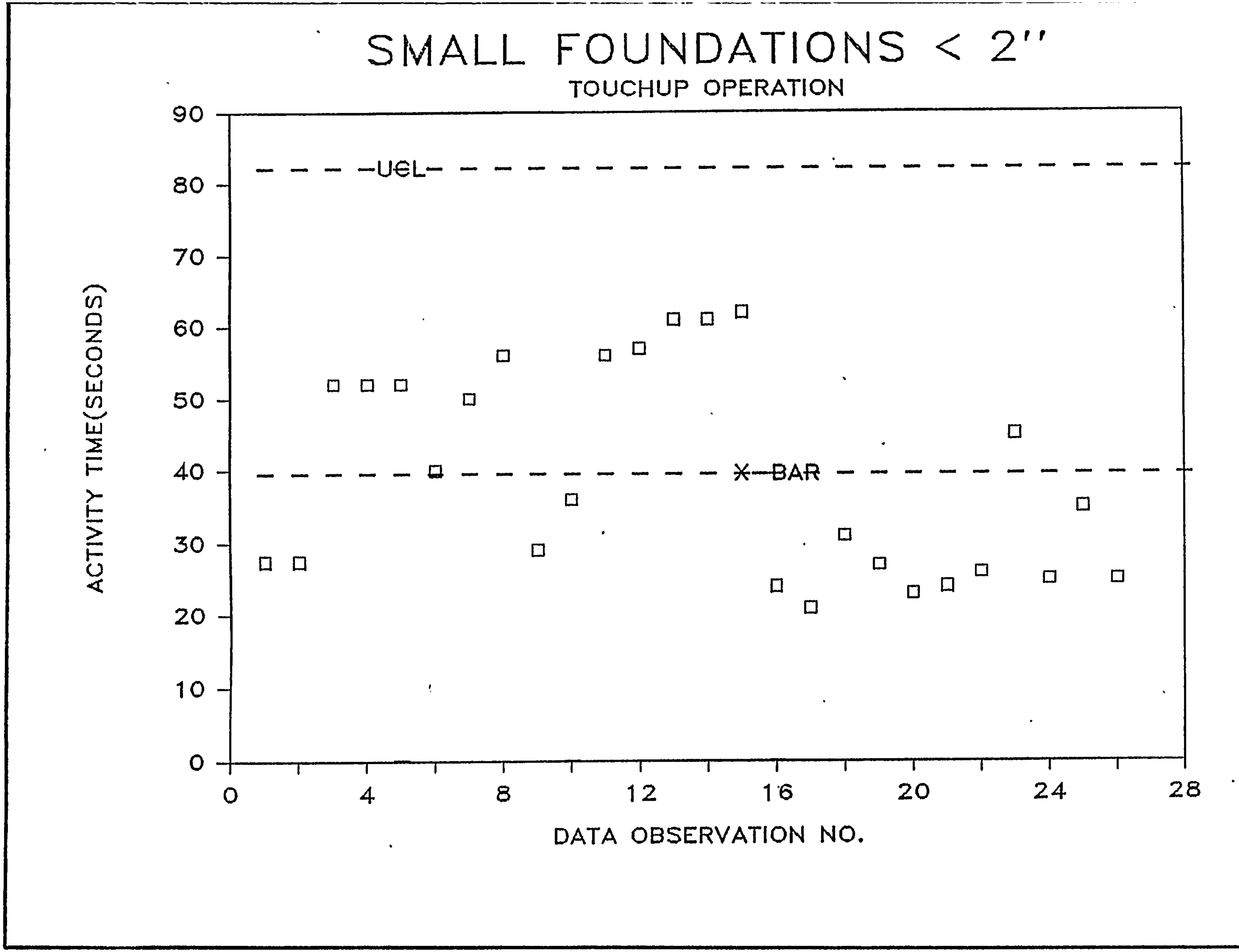


FIGURE 4-3: DEVELOPMENT OF ESTIMATE BY SIMPLE AVERAGING

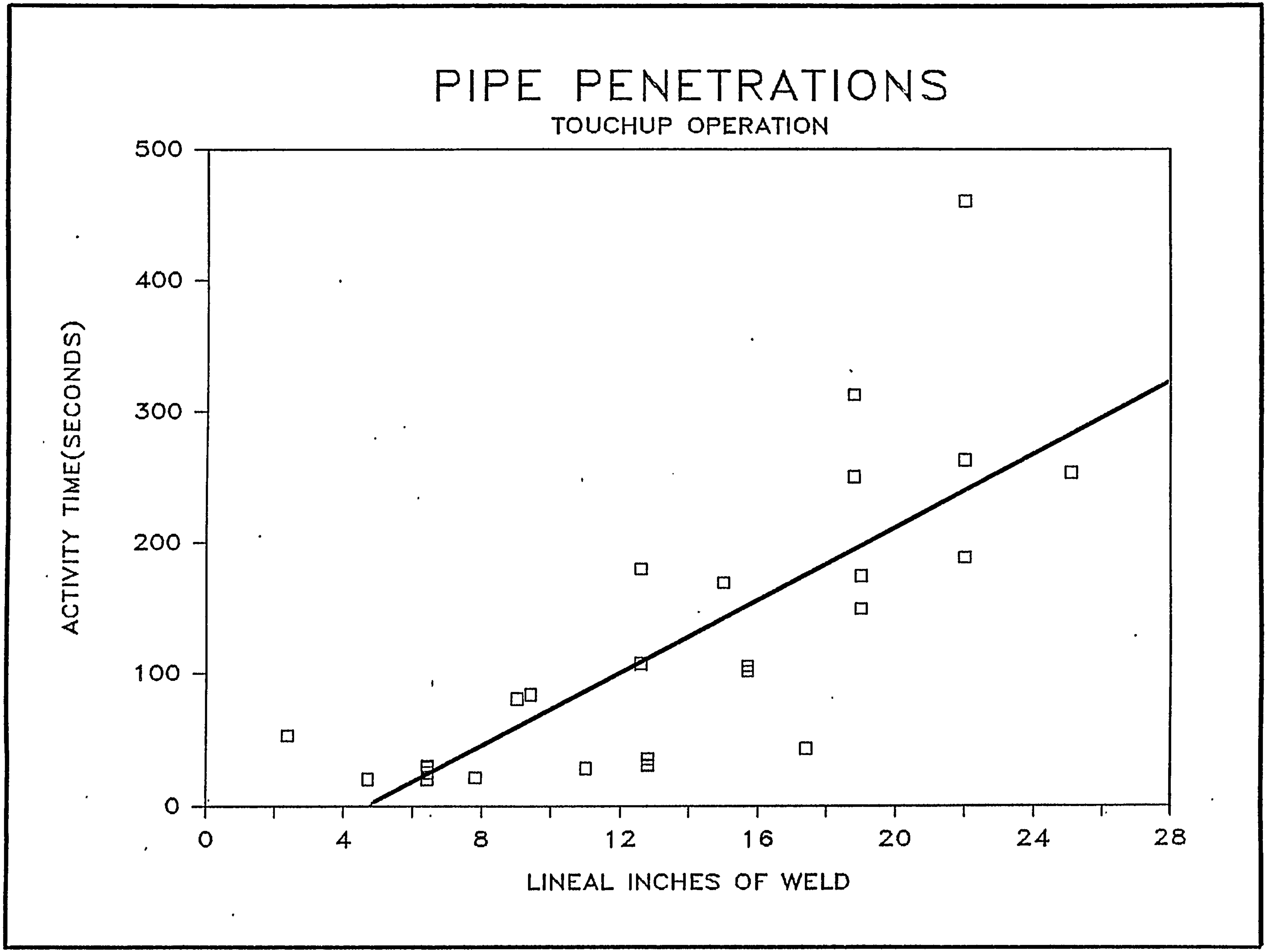


FIGURE 4-4: DEVELOPMENT OF ESTIMATE BY LINEAR REGRESSION

PRIORITY PROGRAM | SHIP: | SECTION: | COMPARTMENT: | REPORT DATE: 01-Feb-85

ALT A = ENTER NEW DATA
ALT B = CALC
ALT C = PRINT RESULTS
ALT D = CLEAR DATA

HOT WORK ITEM	UNIT OF MEASUREMENT	TOTAL HOT WORK (FROM DRAWINGS)	PARTIAL HOT WORK VS PERFORMED	HOT WORK YET TO BE DONE	PERCENT HOT WORK COMPLETE	GRINDING TIME (HRS)	ADJUSTED GRINDING TIME (HRS)	TOUCHUP TIME (HRS)	ADJUSTED TOUCHUP TIME (HRS)	TOTAL TIME (HRS)	TOTAL DOLLARS
DUCT WORK HANGERS	each			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
DUCT WORK PENETRATIONS	lin in			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
DUCT WORK PENETRATIONS(w/collars)	lin in			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
STRUCTURAL COMPENSATION RINGS	lin in			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
FOUNDATIONS > 2" (> 8 " or ERR)	lin in			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
LIGHT FIXTURES HANGERS	each			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
PIPE HANGERS	each			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
PIPE PENETRATIONS(> 4 " or ERR)	lin in			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
SMALL FOUNDATIONS <= 2"	each			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
STUDS	each			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00
WIRE HANGERS(single contact)	each			0	0.00%	0.00	0.00	0.00	0.00	0.00	$0.00

UNNECESSARY/IDENTIFIED HOT WORK DOLLARS:	$0.00
UNNECESSARY/UNIDENTIFIED HOT WORK DOLLARS:	$0.00
TOTAL UNNECESSARY DOLLARS:	$0.00
NECESSARY HOT WORK DOLLARS:	$0.00
GRAND TOTAL:	$0.00

FIGURE 4-5: PRE-OUTFITTING PROGRAM

the drawings. Figure 4-6 displays the results. $ertain hotwork items were being handled properly, while others were not. .

4.5.2 In order to gain some indication of the magnitude of the problem, the program was run for the MMR (Main Machinery Room). The results suggest that $12,000 could be saved in that area alone simply by more extensive pre-outfitting. This same analysis applied to the rest of the ship yielded a possible savings of nearly $240,000 per hull through more extensive pre-outfitting.

4.5.3 Although pre-outfitting technology was available at the beginning of the ARS contract at PBI, the type of quantitative analysis being described here was not. Unfortunately, by the time this estimating capability became available nearly all of the ARS sections had already been blasted and painted, except for the ARS-53 Pilot House. It was therefore suggested that this Pilot House be pre-outfitted as much as possible before blasting and painting. By allowing more time for this added pre-outfitting, about $4,000 in Paint Department touchup costs were saved. The Pilot House turned out to be 78% complete with respect to pre-outfitting, a significant increase compared to, 30% to 40% in other areas.

4.5.4 To support corrective measures, those hotwork items with the greatest potential for cost avoidance needed to be identified so that they could be addressed first. A data collection effort. was performed that identified how much hotwork could be expected in certain types of compartments. Once the quantities were known for the ARS ships, paint rework estimates were applied. This produced a list of hotwork items with the biggest payback. This study shows that if no pre-outfitting is performed, foundations will account for the largest amount of Paint Department touchup and grinding rework hours. That is, if foundations are installed before the sections or panels go through the blast and paint shop, the Paint Department stands to save the most money from pre-outfitting in this particular area. Figure 4-7 shows the rest of the hotwork cost drivers.

4.6 SUMMARY OF REWORK VS. PRE-OUTFITTING

4.6.1 The intention of this portion of Phase I was not to prove or disprove the merits of pre-outfitting. The purpose was to-show that the costs resulting from the lack of pre-outfitting could, in fact, be identified and quantified. Once such information is available, this potential problem area can be investigated. Most certainly, just because savings may be suggested in the Paint Department, this does not mean that the necessary solutions to achieve those savings can be implemented instantly. Indeed, the costs of placing the pre-outfitting technology in operation may be in some areas more costly than the potential savings. The purpose of Phase I, therefore, was to make known the general magnitude of these rework costs so that the expense of implementing a pre-outfitting effort might be compared intelligently.

4.6.2 The potential savings through rework elimination mentioned above are not easily attainable. In fact, a major problem is that savings can be lost quite early in the contract. By the time they show up as cost overruns in the Paint Department planned hours, it may be too late to take corrective measures. If pre-outfitting is to be a part of the shipyard strategy, it should be promoted throughout the shipyard and carried out from the

PRIORITY PROGRAM | SHIP:ARS-52 | SECTION: 601 | COMPARTMENT:ALL | REPORT DATE: 26-Feb-86

ALT A = ENTER NEW DATA
ALT B = CALC
ALT C = PRINT RESULTS
ALT D = CLEAR DATA

HOT WORK ITEM	UNIT OF MEASUREMENT	TOTAL HOT WORK (FROM DRAWINGS)	VS PARTIAL HOT WORK PERFORMED	HOT WORK YET TO BE DONE	PERCENT HOT WORK COMPLETE	GRINDING TIME (HRS)	ADJUSTED GRINDING TIME (HRS)	TOUCHUP TIME (HRS)	ADJUSTED TOUCHUP TIME (HRS)	TOTAL TIME (HRS)	TOTAL DOLLARS
DUCT WORK HANGERS	each	42		42	0.00%	0.86	2.19	1.31	2.97	5.16	***********
DUCT WORK PENETRATIONS	lin in	344		344	0.00%	0.90	2.30	0.29	0.65	2.95	***********
DUCT WORK PENETRATIONS(w/collars)	lin in	675		675	0.00%	2.59	6.58	1.69	3.84	10.42	***********
STRUCTURAL COMPENSATION RINGS	lin in	346	78	268	22.54%	2.04	5.18	0.52	1.19	6.37	***********
FOUNDATIONS > 2" (> 8 " or ERR)	lin in	567	239	328	42.15%	0.76	1.94	2.85	6.46	8.41	***********
LIGHT FIXTURES HANGERS	each	10		10	0.00%	0.25	0.64	0.18	0.41	1.05	***********
PIPE HANGERS	each	119		119	0.00%	1.87	4.77	1.37	3.10	7.87	***********
PIPE PENETRATIONS(> 4 " or ERR)	lin in	723		723	0.00%	6.81	17.33	5.55	12.57	29.90	***********
SMALL FOUNDATIONS <= 2"	each	123	4	119	3.25%	3.42	8.70	1.30	2.95	11.65	***********
STUDS	each	2597	2597	0	0.00%	0.00	0.00	0.00	0.00	0.00	***********
WIRE HANGERS(single contact)	each	52	16	36	30.77%	0.88	2.24	0.73	1.65	3.88	***********

UNNECESSARY/IDENTIFIED HOT WORK DOLLARS:	***********
UNNECESSARY/UNIDENTIFIED HOT WORK DOLLARS:	***********
TOTAL UNNECESSARY DOLLARS:	***********
NECESSARY HOT WORK DOLLARS:	***********
GRAND TOTAL:	***********

FIGURE 4-6: PRE-OUTFITTING PROGRAM (ARS-52, SECTION 601)

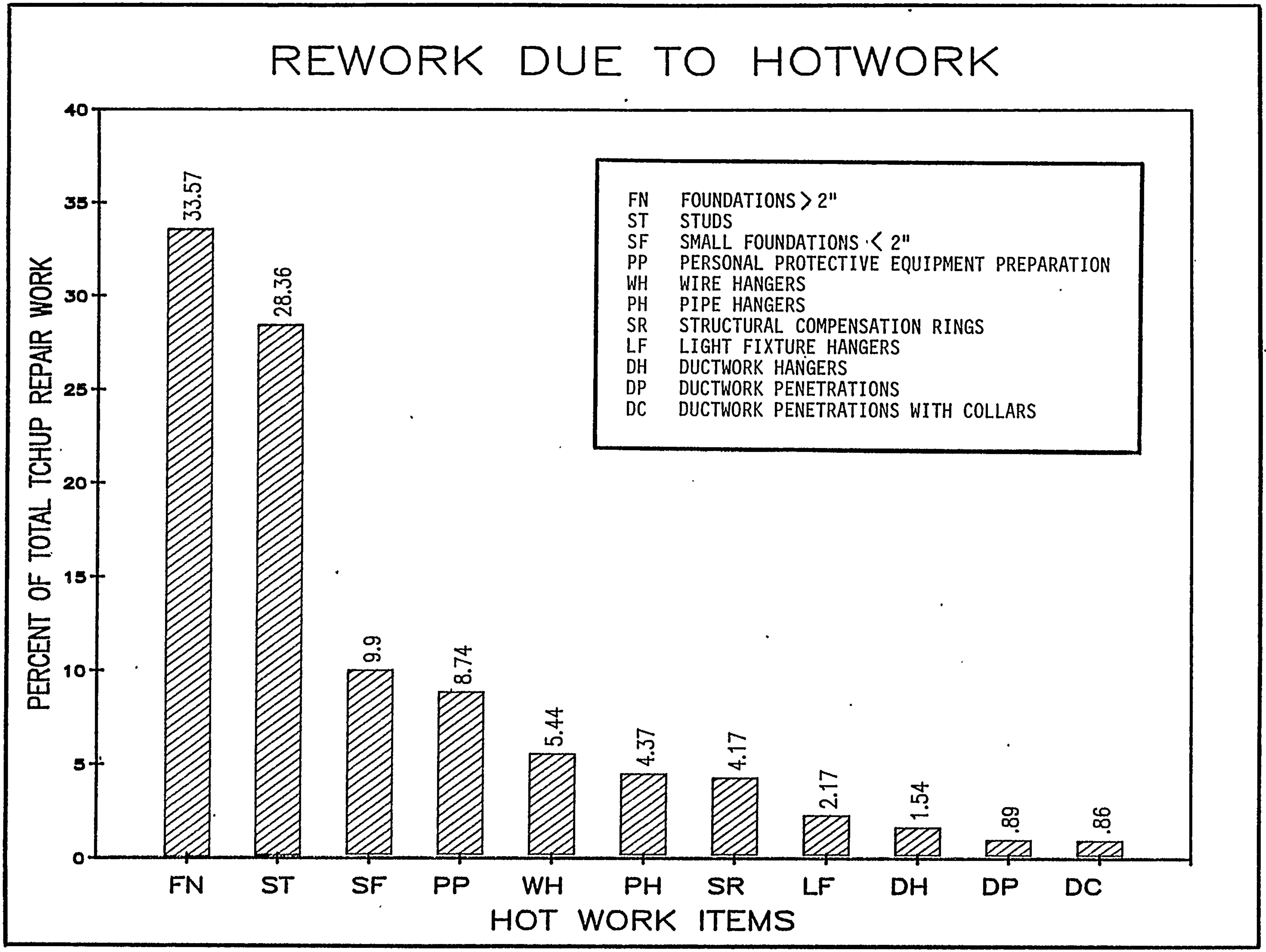

REWORK DUE TO HOTWORK
PERCENT OF TOTAL TCHUP REPAIR WORK
0
5
10
15
20
25
30
35
40
33.57
28.36
9.9
8.74
5.44
4.37
4.17
2.17
1.54
.89
.86
FN FOUNDATIONS > 2"
ST STUDS
SF SMALL FOUNDATIONS < 2"
PP PERSONAL PROTECTIVE EQUIPMENT PREPARATION
WH WIRE HANGERS
PH PIPE HANGERS
SR STRUCTURAL COMPENSATION RINGS
LF LIGHT FIXTURE HANGERS
DH DUCTWORK HANGERS
DP DUCTWORK PENETRATIONS
DC DUCTWORK PENETRATIONS WITH COLLARS
FN
ST
SF
PP
WH
PH
SR
LF
DH
DP
DC
HOT WORK ITEMS

FIGURE 4-7

beginning of the contract work. The need for the earliest possible recognition of rework costs has argued in favor of Phases II and III of this project. A brief discussion of these follow-on efforts is provided below.

5.0 PREPARATIONS FOR PHASE II - BID STAGE ESTIMATING

5.1 DATABASE UPGRADE

5.1.1 As mentioned in the Introduction, it became evident .as the Project unfolded that far greater benefits could be realized if the data collection effort were expanded. By collecting more detailed data, we would not only identify more precisely the costs of painting but could support follow-on studies in the cost control area. Consequently, midway through Phase I the Project was expanded to widen the scope of the data collection effort. The goal was to put in place a data collection effort that would suit Phase I, and also support Phase II (Bid Stage Estimating) and Phase III (Earlier Recognition of Cost Variances).

5.1.2 Data related to the Paint Department was available from two information systems, the shipyard's Labor Reporting System and the Paint Department's Job Reporting System. Unfortunately the daily shipyard system was too general and could not be used to address the detail needed for shop management. Although the shop system addressed most of the detail needed, the data was handled manually and soon became too cumbersome for updating and retrieving information.

5.1.3 In view of the above shortcomings in the existing data collection systems, a new Labor Reporting System was developed. This new system accepts far more detailed data from the worker. Once these data are entered into the system, the computer reorganizes the data into several reports which provide the information needed by shop management. The new Labor Reporting System was initiated during the summer of 1985. The system is now used on every ship that PBI has under construction, and is planned for implementation on all future contracts. Included under this new system are the MCM ships (of wooden construction), which illustrates the flexibility of the system and its application on varying types of contracts.

. 5.1.4 The details of this new Labor Reporting System are as follows. The system consists of daily work cards, labor reporting books, and an micro-computer. The labor cards are filled out daily by each worker, who is responsible for providing all the information requested except for the location where the work was performed. Figure 5-1 shows a sample work card. The cards are turned in to the leadman who identifies the assembly and compartment where the work was performed. The leadman then enteri the information from the work card into the labor reporting book. (Note: The manual aspect of the labor reporting books is temporary. The original intent of these books - one per ship - was to help the Paint Department personnel to familiarize themselves with the data collection process. Eventually the labor reporting books will be discontinued.) Finally, the information from the labor reporting books is ,entered into the computer by a data entry clerk. Labor Status Reports are then generated for use by the Paint Department Supervisor. These reports are described below.

NAME: ______________________________ SHIFT: 1 2 3 DATE: ____________________

OPERATION CODES:

GR = GRIND
SB = SAND BLAST
SD = SAND
TP = TAPE
CL = CLEAN
PT = PAINT
TU = TOUCHUP
UT = UNTAPE
CK = CAULK
FH = FILL SCREW HOLES
GC = GEL COAT
ST = STENCILING
OT = OTHER

FOR ALL REWORK OPERATIONS
PLACE AN 'R' IN FRONT OF
OPERATION CODE, FOR EXAMPLE:

REWORK GRINDING = RGR

REWORK TOUCHUP = RTU

ETC.

REWORK DESCRIPTIONS:

DP = DUCTWORK PENETATIONS
DH = DUCTWORK HANGERS
SC = STRUCTURAL COMPENSATION RINGS
FD = FOUNDATIONS
LH = LIGHT FIXTURE HANGERS
PH = PIPE HANGERS
PP = PIPE PENETRATIONS
IS = INSULATING STUDS
WS = WIRE WAY STUDS
OT = OTHER

HULL	ASSEMBLY	COMPARTMENT	COAT NO.	OPER CODE	HOURS	GALS.	PT TYPE	COMMENTS
				-				
				-				
				-				
				-				
				-				
				-				
				-				
				-				

FIGURE 5-1: PAINT DEPT. WORK CARD

5.1.5 Further improvements in the data collection system are anticipated. Although the reporting system now satisfies the Phase 11 and Phase III requirements for data, there is room for automation in the data collection process. Throughout 1986 a marrying effort with the mainframe labor collection system at PBI will take place.

5.2 SHIP LABOR STATUS REPORTS

5.2.1 A commercially available statistical analysis program called SPSS/PC (Statistical Package for the Social Sciences) is the software used to generate the labor reports. A status report. is generated for each hull, and consists of three sub-reports, as follows:

5.2.1.1 HOURS USED BY OPERATION

This report breaks down all recorded hours into the different operations and sums up these hours by assembly, by compartment, and by coat number. This report, shown by Figure 5-2, is useful in determining the progress of painting work in compartments throughout the ship.

5.2.1.2 REWORK ENCOUNTERED BY SOURCE

Rework is recorded as separate operation in the labor reporting books. Each rework entry also includes remarks describing the source of rework, such as a pipe penetration, ductwork hanger, etc. The rework report breaks down all the ‘rework hours by department source, and sums them up by operation, such as grinding or touchup. This department report is shown by Figure 5-3.

5.2.1.3 GALLONS USED BY TYPE

This report breaks down, by paint type, the gallons of paint used for painting, for touchup, and for rework. This information, along with the other ship reports, can be used in tracking and forecasting paint requirements. See Figure 5-4.

5.3 SHOP LABOR STATUS REPORTS

5.3.1 An additional report deals with the blast and paint shop. It has been difficult to account for the usage of manhours in this facility, due mostly to the fact that the small parts going through the shop have great variability associated with them. The small parts may come from any shop in the shipyard; they can be as small as a clip or as large as an anchor, and they may be in any quantity. Even though the blasting and painting of small parts was recognized as a difficult area to control, it was deemed essential that all areas be covered by the data collection effort in order to produce a complete Paint Department database. A data collection effort was therefore initiated, and a small parts status report was generated from the collected data. Within the small parts report there are three sub-reports, as follows:

5.3.1.1 1 BLAST AND PAINT SHOP: HOURS BY DEPARTMENT SOURCE AND OPERATION CODE.

This report breaks down the manhours by the department source of the small part, and by an operation code which refers to painting, sandblasting, taping, etc. This report is shown by Figure 5-5.

HULL	SECT	COMPT	CT	GR	SB	SD	CL	TP	PT	TU	UT	ST	FH	GC	FS	CK	PR	PC	WP	OT	RW
53	601	02394Q	NA	.	2.50	.	3.00	.	1.50	1.00	2.00	.	.	.	2.00	.	.	.	.	.	.
		SUM		.	2.50	.	3.00	.	1.50	1.00	2.00	.	.	.	2.00	.	.	.	.	.	.
		ALL	1	.	.	.	9.00	16.00	15.00	.	.	.	.	.	.	.	.	.	.	.	16.00
			NA	16.00	.	.	4.50	5.00	5.00	1.00	.	.	.	.	.	.	.	.	.	15.00	22.50
			P	.	14.00	.	22.00	12.00	22.00	16.00	.	.	.	.	.	.	.	.	.	.	.
		SUM		16.00	14.00	.	35.50	33.00	42.00	17.00	.	.	.	.	.	.	.	.	.	15.00	38.50
		01322Q	1	.	.	.	.	.	3.00	.	.	.	.	.	.	.	.	.	.	.	10.00
			NA	3.00	23.00	.	32.50	12.00	8.00	2.00	.	.	.	.	.	.	.	.	.	24.50	3.50
			P	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6.00	.
		SUM		3.00	23.00	.	32.50	12.00	11.00	2.00	.	.	.	.	.	.	.	.	.	30.50	13.50
	SUM			19.00	54.50	.	141.7	61.00	157.9	36.00	9.00	.	.	.	9.00	.	.	.	.	72.50	92.50
	602	01310L	1	.	.	.	.	.	2.00	.	.	.	.	.	.	.	.	.	.	.	3.00
			2	.	.	.	.	.	1.50	.	.	.	.	.	.	.	.	.	.	.	.
			NA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3.00
		SUM		.	.	.	.	.	3.50	.	.	.	.	.	.	.	.	.	.	.	6.00
		01460L	1	.	.	.	.	.	2.00	.	.	.	.	.	.	.	.	.	.	.	.
		SUM		.	.	.	.	.	2.00	.	.	.	.	.	.	.	.	.	.	.	.
		01462Q	1	.	3.00	.	3.00	11.50	4.50	.	.	.	.	.	13.00	.	.	.	.	.	.
			NA	2.00	.	.	.	.	.	.	1.50	.	.	.	.	.	.	.	.	1.00	.
		SUM		2.00	3.00	.	3.00	11.50	4.50	.	1.50	.	.	.	13.00	.	.	.	.	1.00	.
		01491Q	NA	1.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		SUM		1.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		01492C	1	.	.	.	2.00	4.00	32.50	.	.	.	.	.	.	.	.	.	.	.	.
			2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8.10
			F	.	.	.	.	.	4.00	.	.	.	.	.	.	.	.	.	.	.	12.00
			NA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	41.00

FIGURE 5-2: ARS-53 HOURS SUMMARY (PARTIAL)

REWORK HOURS & GALLONS OF PAINT USED

HULL	DEPT. #	OPER CODE	HOURS	GALLONS OF PAINT
53	11	CL	7.00	0.00
		GR	5.00	0.00
		PT	11.00	5.00
		SB	4.00	0.00
		TU	63.00	1.75
	SUM		90.00	6.75
	12	CL	75.00	0.00
		GR	552.25	.18
		PT	64.50	13.75
		SB	37.00	0.00
		SD	24.50	0.00
		TU	182.75	16.19
	SUM		936.00	30.12
	13	CL	3.00	0.00
		GR	20.50	0.00
		PT	5.00	1.00
		TU	7.50	.37
	SUM		36.00	1.37
	14	CL	404.50	1.00
		GR	1856.00	0.00
		PT	92.50	49.62
		RW	9.00	0.00
		SD	21.00	0.00
		TU	236.20	31.31
	SUM		2619.20	81.93
	17	CL	38.50	0.00
		GR	109.50	.12
		PT	17.00	2.12
		SD	5.50	0.00
		TP	4.00	0.00
		TU	207.50	11.06
		UT	1.00	0.00
	SUM		383.00	13.30
	19	CL	29.00	0.00
		GR	143.00	0.00
		PT	7.00	0.00
		TU	21.00	6.75
	SUM		200.00	6.75
	23	CL	1.00	0.00
		SD	4.00	0.00

FIGURE 5-3: ARS 53 - REWORK SUMMARY (PARTIAL)

TOTAL GALLONS OF PAINT BY PAINT TYPE & TYPE OF WORK

HULL	PAINT TYPE	PAINT GALLONS	TOUCHUP GALLONS	STENCIL GALLONS	REWORK GALLONS
53	5001	115.37	35.87	.	50.96
	500100	.12	.	.	.
	500101	3.75	.	.	.
	500102	1134.06	158.69	.	165.33
	500104	.	.	.	.12
	500107	.	.	.	.25
	500501	20.00	.	.	.
	5006	44.00	8.75	.	.
	500600	25.82	.50	.	1.56
	500601	200.81	11.02	.	20.37
	500602	37.50	1.37	.	.62
	500603	19.98	1.49	.	2.25
	500605	.50	.	.	.
	500607	.25	.	.	.
	5007	.	.	.	.12
	600601	.	.12	.	.
	634	20.36	8.50	.	.
	ALUM	5.50	.	.	.
	ANTISWT	10.87	.50	.	.50
	ASPHTV	1.50	.	.	.
	COALTR	1.00	.	.	.
	F124	3.00	.	.	.
	F125	.	.	.	.06
	F34	1.37	.	.	.
	F634	2.00	.	.	.
	FIRERT	45.50	.	.	.

FIGURE 5-4: ARS 53 - GALLON USAGE SUMMARY (PARTIAL)

PAINT DEPARTMENT - SMALL PARTS
BROKEN DOWN BY DEPT & OPCODE

DEPT. SOURCE	TOTAL HOURS	PT	SB	TP	UT	CE	CA	CP	CS	OT	RW	TOTAL GALLONS
-1	1.25	.63	.63	.	.	.	.	.	.	.	.	1.00
11	249.81	197.0	17.49	24.62	.	.	.	.	5.00	.	67.61	296.06
12	670.76	501.6	126.9	27.78	1.00	.	5.50	.	5.50	.	117.2	750.98
13	250.72	204.5	42.31	1.88	.	.	.	.50	1.00	.	7.88	267.24
14	112.25	75.12	36.38	.25	.	.	.	.	.50	.	8.00	112.94
141	42.60	27.57	14.79	.25	.	.	.	.	.	.	.	49.73
144	.25	.25	.	.	.	.	.	.	.	.	.	.24
15	23.19	17.31	3.38	1.50	1.00	.	.	.	.	.	.50	32.98
16	36.12	21.12	1.50	9.00	4.00	.	.	.	.	.	.	22.37
17	132.68	129.2	2.75	.	.	.	.	.	.75	.	5.00	184.77
23	41.88	10.00	9.63	.25	.	14.00	.	8.00	.	.	.50	13.00
25	3.00	3.00	.	.	.	.	.	.	.	.	.	6.75
29	9.11	7.36	1.74	.	.	.	.	.	.	.	2.49	11.73
3	6.12	6.12	.	.	.	.	.	.	.	.	.12	9.24
31	.63	.50	.13	.	.	.	.	.	.	.	.	.37
32	.50	.50	.	.	.	.	.	.	.	.	.	1.00
33	47.49	40.99	5.75	.25	.	.	.	.	.50	.	1.13	44.97
34	32.50	20.00	10.50	.	.	.	.	2.00	.	.	.	62.00
35	65.80	64.80	.	.	.	.	.	.	1.00	.	.25	103.71
36	4.00	.	.	.	.	.	.	4.00	.	.	.	.
38	1.00	.50	.50	.	.	.	.	.	.	.	.	2.50
45	59.50	47.50	8.00	3.00	1.00	.	.	.	.	.	7.00	114.00
GEN	16.00	16.00	.	.	.	.	.	.	.	.	.	48.50
.	.	.	.	.	.	.	.	.	.	.	.	.
YARD	2.75	2.75	.	.	.	.	.	.	.	.	.	7.00

FIGURE 5-5: BLAST AND PAINT SHOP HOURS SUMMARY BY DEPT. SOURCE (PARTIAL)

5.3.1.2 MANHOURS BY CONTRACT AND HULL

This second sub-report, shown by Figure 5-6, is similar to the first one in that it is broken down by operation. The sort, however, is by contract rather than by department source.

5.3.1.3 PAINT FACILITY PAINT TYPES

The last sub-report, shown by Figure 5-7, covers the types of paint being used by the facility. It is a fallout of the information generated for the first two sub-reports. It has been added to the overall small parts status report because of its usefulness in keeping track of the paint expended.

5.4 EXAMINATION OF COMPARTMENT COMPLEXITY

5.4.1 In planning for the Phase II Bid Stage Estimating portion of the Project (to take place during 1986 as a FY-85 effort), it was recognized that the detailed estimating capability being pursued would require additional information dealing with the complexity of the ship-compartment. Because of the varying degrees of complexity in ship compartments the ability to estimate certain Paint Department activities has been Weak, due principally to the numerous independent variables that are present. These independent variables are any factors that influence the time (the dependent variable) that it takes to paint a compartment. Simple averaging and linear regression analysis can no longer provide reliable estimates. The estimating process must take one step further and begin to use multiple regression analysis.

5.4.2 Discussions have been held with several experts about the use of multiple regression analysis as an estimating tool. Dr. Robert J. Graves of the University of Massachusetts at Amherst, Dr. Leon F. McGinnis of the Georgia Institute of Technology, Dr. Kenneth Kundert of the University of Wisconsin at Platteville, and Mr. Rodney A. Robinson of Robinson-page-McDonough and Associates, Inc. have all agreed that because of the significant amount of outside influences on painting operations the best estimates will probably be derived by this method. This type of analysis is not new to the shipyard environment. In fact, during a 1982 Scheduling Standards Pilot Project at PBI under the NSRP, Mr. Robinson and Dr. Graves concluded that, “Scheduling Standards accurately predict the manhours required to fabricate individual piping assemblies”. The report on this pilot project goes on to say that this type of analysis greatly reduces the effort required of shipyard personnel in developing shipbuilding standards over the more traditional procedures (MTM, MOST, etc.).

5.4.3 Although the majority of the analyses are planned for Phase 11, preliminary work during Phase I has already identified several influential factors. These factors are listed in Figure 5-8. The data collection effort to support further treatment of this area consists of rating the compartments onboard ship with respect to several identified influential variables. Three ships are being rated at the present time; ARS-52, ARS-53, and MCM-1. The process is being carried out once each month. Figure 5-9 shows a sample data collection form. During Phase II, the complexity ratings and the recorded manhours will be entered into a multiple regression program leading to development of appropriate estimating equations. The program will accomplish this task by deleting the non-influential variables

PAINT DEPARTMENT - SMALL PARTS
BROKEN DOWN BY CONTRACT & HULL

CONTRACT	HULL	TOTAL HOURS	PT	SB	TP	UT	CE	CA	CP	CS	OT	RW	TOTAL GALLONS
ARS	50	5.00	3.88	1.13	.	.	.	.	.	.	.	.	3.30
	51	124.72	88.77	26.75	9.20	.	.	.	.	.	.	44.61	88.22
	52	397.27	290.9	74.10	20.08	.	.	5.00	2.00	.50	.	102.3	508.02
	53	319.26	202.5	97.05	13.75	1.00	.	.	.	2.00	.	32.36	263.07
	GEN	125.50	84.46	39.79	.25	.	.	.	.50	.	.	.50	114.48
SUM		971.74	670.5	238.8	43.28	1.00	.	5.00	2.50	2.50	.	179.8	977.09
BLD	21	1.00	1.00	.	.	.	.	.	.	.	.	.	1.00
SUM		1.00	1.00	.	.	.	.	.	.	.	.	.	1.00
MCM	1	569.66	533.5	1.63	20.25	6.00	.	.50	.	6.75	.	29.62	872.59
	3	91.68	80.68	2.00	4.00	.	.	.	.	5.00	.	4.00	119.53
	5	23.18	23.18	.	.	.	.	.	.	.	.	2.25	33.28
	52	.50	.50	.	.	.	.	.	.	.	.	.	.25
	GEN	2.00	2.00	.	.	.	.	.	.	.	.	.	2.50
SUM		687.02	639.9	3.63	24.25	6.00	.	.50	.	11.75	.	35.87	1028.15
TESTC	TESTC	1.25	.50	.75	.	.	.	.	.	.	.	.	.50
SUM		1.25	.50	.75	.	.	.	.	.	.	.	.	.50
.	.	1.12	.62	.50	.	.	.	.	.	.	.	.	2.74
SUM		1.12	.62	.50	.	.	.	.	.	.	.	.	2.74
YARD	BDG44	16.00	.	.	.	.	14.00	.	2.00	.	.	.	.
	BSHED	4.00	.	.	.	.	.	.	4.00	.	.	.	.
	YARD	117.75	73.62	37.87	.25	.	.	.	6.00	.	.	.	126.24
SUM		137.75	73.62	37.87	.25	.	14.00	.	12.00	.	.	.	126.24
YP	682	10.00	8.25	.75	1.00	.	.	.	.	.	.	2.00	7.36
SUM		10.00	8.25	.75	1.00	.	.	.	.	.	.	2.00	7.36

FIGURE 5-6: BLAST AND PAINT SHOP HOURS SUMMARY BY CONTRACT (PARTIAL)

PAINT DEPARTMENT - SMALL PARTS
BROKEN DOWN PAINT TYPE

CONTRACT	PAINT TYPE	PAINT GALLONS	REWORK GALLONS
ARS	500604	2.00	1.50
	500605	.25	.25
	500607	1.00	.
	800593	.50	.
	84	1.00	.
	ANTISWET	6.00	.
	ASPHVAR	19.86	.
	F111	34.83	3.25
	PASTBLU	.50	.50
	PASTGRN	4.58	2.37
	PBIBLUE	1.50	.
	SAFTRED	2.00	.
	SAFTYEL	1.50	.
	SAFTYRED	10.73	.
	SAFYTRED	1.00	.
	TTE490	85.35	16.24
	VINEXGY	1.50	.
	XX	.74	.50
SUM		977.09	123.15
BLD	477	1.00	.
SUM		1.00	.
MCM	120	.50	.
	124	219.05	12.12
	125	.50	.
	150	427.55	17.24
	151	44.74	.50

FIGURE 5-7: BLAST AND PAINT SHOP GALLON USAGE SUMMARY (PARTIAL)

INFLUENTIAL COMPARTMENT COMPLEXITY FACTORS

SQUARE FEET
ACCESSIBILITY
LOCATION(SHIP LEVEL)
NUMBER OF PAINT TYPES
NUMBER OF INSULATED BULKHEADS
NUMBER OF PAINTED BULKHEADS
AMOUNT OF HANGERS, FOUNDATIONS, BRACKETS
AMOUNT OF WIRING
AMOUNT OF PIPING
AMOUNT OF ELECTRICAL PANELS
AMOUNT OF MACHINERY AND EQUIPMENT
AMOUNT OF FURNITURE

FIGURE 5-8

PBI-PAINT DEPT. COMPARTMENT COMPLEXITY RATING SYSTEM

ACCESSIBILITY: 1=EXCELLENT 2=GOOD 3=ABOVE AVG.
4=AVG. 5=BELOW AVG. 6=POOR 7=VERY POOR

LOCATION: 1=MAIN DECK 2=01 LEVEL,PLATFORM 3=02 LEVEL,HOLD
4=02 LEVEL,DOUBLE BOTTOM 5=03 LEVEL 6=04 LEVEL

AMOUNT OF/ROOM SIZE: 1=NONE 2=FEW 3=BELOW AVG. 4=AVG.
5=ABOVE AVG. 6=MANY 7=EXCESSIVE

SECTION: 406 COMPARTMENT: 1-6-0-E TYPE: MS

DATE	ACCESS	LOC	NO OF PNT TYPES	NO OF INSUL WALLS	NO OF PNT'D WALLS	HNGRS FONDS BRKTS	WIRES	PIP'G	ELEC PNLS	MACH EQUIP	FURN
10-7	5	1	1	5	6	5	5	5	5	6	1
1-18	5	1	1	5	6	5	5	4	5	6	1
12-6	5	1	1	5	6	5	5	4	5	6	1

SECTION: 406 COMPARTMENT: 1-11-1-Q TYPE: WK

DATE	ACCESS	LOC	NO OF PNT TYPES	NO OF INSUL WALLS	NO OF PNT'D WALLS	HNGRS FONDS BRKTS	WIRES	PIP'G	ELEC PNLS	MACH EQUIP	FURN
10-7	3	1	1	3	4	4	4	3	5	3	1
11-11	3	1	1	3	4	4	4	3	5	4	1
12-6	3	1	1	3	4	4	4	3	5	4	3

SECTION: 406 COMPARTMENT: 1-16-1-L TYPE: PS

DATE	ACCESS	LOC	NO OF PNT TYPES	NO OF INSUL WALLS	NO OF PNT'D WALLS	HNGRS FONDS BRKTS	WIRES	PIP'G	ELEC PNLS	MACH EQUIP	FURN
10-7	1	1	1	3	2	3	3	2	2	1	1
11-11	2	1	1	3	2	3	3	2	2	1	1
12-6	2	1	2	3	2	3	3	2	3	1	4

FIGURE 5-9: COMPARTMENT COMPLEXITY RATING DATA SHEET

and keeping the influential variables. A simple equation with possibly three or four independent variables will then be used to estimate the dependent variable. Figure 5-10 is provided to illustrate an example of multiple regression analysis leading to an estimating equation.

6.0 SUPPORT OF PHASE III - EARLIER RECOGNITION OF VARIANCES

6.1 The database developed for Phase I and expanded to suit Phase II contains a feedback system well suited to the control of cost variances-by shop management. Upper and lower control limits for the several Paint Department operations will accompany the basic estimates of cost. Whenever the predetermined control limits are violated, shop management will receive immediate notification of the excursion, and will be able to apply corrective measures promptly. Much effort remains to mold this system into a truly practical and efficient tool for use by shop management, but the prospects for success are high.

7.0 SUMMARY

7.1 At this point in the Project it is evident that “painting” in the shipyard is far more involved than was first anticipated, and not a simple task. The hours that are consumed in surface preparation far exceed the. time required to lay on the paint. Clearly; the collateral costs associated with the painting operation, and identified in this report in Phase I, cannot be ignored and MUST be factored into the estimate, or else the reliability of the estimate will suffer badly. In the present competitive atmosphere when fixed price contracts are becoming the rule rather than the exception, the attainment of reliable estimates cannot be treated lightly if the shipyard is to survive in the market place.

7.2 One bright aspect of the detailed study on how much the lack of pre-outfitting can actually cost is the finding that the Paint Department can be of tremendous help in identifying problem areas. Since the paint Department is usually the last one in an area before it is closed out, they can provide an excellent check on whether the other trades were able to complete their work as scheduled.

MULTIPLE REGRESSION ANALYSIS

EXAMPLE:

ACTIVITY - PAINTING

DEPENDENT VARIABLE - HOURS

INITIAL VARIABLES

SQUGRE FEET
ACCESSIBILITY
HANGERS, FOUNDATIONS, BRACKETS
DUCTWORK AND PIPING
ELECTRICAL PANELS
FURNITURE

COMPARTMENT LOCATION
NLIMBER PAINTED BULKHEADS
NUMBER lNSULATED BULKHEADS
MACHINERY AND EQUIPMENT
WIRES

AFTER SPSS REGRESSION ANALYSIS

POSSIBLE VARIABLES

SQFT
ACCESSIBILITY

MACHINERY AND EQUIPMENT
FURNITURE

REGRESSION EQUATION

HOURS = 1.35(SQFT) + .ll(ACCESSIBILTY) +

.24(MACHINERY AND EQUIPMENT) + .09(FURNITURE) + .20

FIGURE 5-10

APPENDIX A

ACKNOWLEDGEMENTS AND SOURCES OF INFORMATION

The following Companies provided information on existing systems for identifying the cost of surface preparation and painting:

* Avondale Shipyards, Inc.
* National Steel and Shipbuilding Company
* Todd Pacific Shipyards Corporation, Los Angeles Division
* Mare Island Naval Shipyard
* Bath Iron Works Corporation
* Bay Shipbuilding Corporation
* Southwest Marine, Inc.
* Pro-Line Paint Manufacturing Company

The following individuals provided consulting services during the Project:

* Dr. Robert J. Graves
* Dr. Leon F. McGinnis
* Mr. Rodney A. Robinson
* Dr. Kenneth Kundert
* Mr. Phil Sands
* Mr. Paul Vickers

The following software packages were used through the Project:

* SPSSPC, SPSS Inc.
* LOTUS 1.2.3, LOTUS Development Corp.
* CHARTMASTER, Decision Resources Inc.

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